



ASTROPHYSICAL VIRTUAL OBSERVATORY

1st Annual Report

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RTD Project Title	Astrophysical Virtual Observatory
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Partnership Summary

Participant Number (Coordinating partner as participant N°1)	Name of Participating Organisation	Role in Project*
1	European Southern Observatory	CO
2	Space Telescope European Coordinating Facility	CR
3	University of Edinburgh	CR
4	Centre National de la Reserche Scientifique Délégation Alsace	CR
4	University Louis Pasteur	CR
5	Centre National de la Reserche Scientifique Délégation Paris	CR
6	The Victoria University of Manchester	CR

- * LSF-IHP: a research infrastructure funded for access under the IHP programme
 LSF-TMR: a research infrastructure funded for access under the TMR programme
 LSF-OTH: a research infrastructure outside the IHP or TMR programmes
 IND: an industrial or commercial enterprise
 OTHER: other types of participant

1.0 EXECUTIVE SUMMARY.....	4
1.1 Objectives	4
1.2 Results	4
1.3 Project Manager Information.....	4
2.0 SCIENTIFIC AND TECHNICAL PERFORMANCE	5
2.1 Summary of project objectives for year 1	5
2.2 Technical Progress – Work Area 0 – Program Management	6
2.2.1 Program Management – WP 0.1	6
2.2.2 Phase B Plan – WP 0.2	6
2.2A Technical progress - Work Area 1 – Science.....	6
2.2A.1 Definition of the AVO Science Reference Mission- WP 1.1	6
2.2A.2 Definition of the AVO Scientific requirements - WP 1.2	7
2.2A.3 Pilot implementation of selected science cases - WP 1.3	8
2.2B Technical progress - Work Area 2 – Interoperability	9
2.2B.1. Inclusion of archives in the interoperability system – WP 2.1	9
2.2B.2. Running of tests and evaluation of results – WP 2.2	10
2.2B.3. Implementation of new functionalities and standards – WP2.3	11
2.2B.4 Evaluation of interoperability tools – WP2.4.....	13
2.2C Technical progress - Work Area 3– Technology	13
2.2C.1 Grid Technology - WP3.1.....	14
2.2C.2 Storage/Compute Technology - WP3.2.....	15
2.2C.3 Database Technology - WP3.3	15
2.3 Planned Activities and Actual Work.....	16
2.3.1 Work-package 0.1: Program Management	16
2.3.2 Work-package 0.2: Phase B Plan	16
2.3.3 Work-package 1.1: Definition of the AVO Science Reference Mission	16
2.3.4 Work-package 1.2: Definition of the AVO Scientific requirements.....	16
2.3.5 Work-package 1.3: Pilot implementation of selected science cases	17
2.3.6 Work-package 2.1: Inclusion of archives in the interoperability system.....	17
2.3.7 Work-package 2.2: Running of tests and evaluation of results	17
2.3.8 Work-package 2.3: Implementation of new functionalities and standards	17
2.3.9 Work-package 3.1: Grid Technology.....	18
2.3.10 Work-package 3.2 Storage/Compute Technology.....	18
2.3.11 Work-package 3.3: Database Technology	18
2.4 Planned Activities for Year 2	19
2.4.1 Work Area 0 Activities.....	19
2.4.2 Work Area 1 Activities.....	19
2.4.3 Work Area 2 Activities.....	19
2.4.4 Work Area 3 Activities.....	19
3.0 LIST OF DELIVERABLES	20
4.0 EXPLOITATION AND DISSEMINATION OF RESULTS	21
4.1 Conferences:.....	21

4.2 International Press: 21

4.3 Presentations and Papers: 21

5.0 MANAGEMENT AND COORDINATION ASPECTS 23

5.1 Project Communications 23

 5.1.1 Project meetings 23

 5.1.2 Technical meetings 23

 5.1.3 Intranet 23

 5.1.4 Telephone Conferencing 23

5.2 Manpower allocation and utilization 26

5.3 Project Budgets 26

5.4 Attribution of tasks 28

6 APPENDICES 29

Appendix A – Terms of Reference and membership of the AVO SWG 29

 AVO SWG – Principal Members 30

Appendix B – Cost Statements 31

1.0 Executive Summary

The AVO contract (HPRI-CT-2001-50030) began on 1 November 2001. The project aims within a three year work program to lay the scientific and technical basis for an operational virtual observatory in Europe. The project consists of three main work areas (Science, Interoperability and Technology), utilizes approximately 54 man years of effort involving more than 50 staff spread over six partner organizations and consortia.

1.1 Objectives

The first year of the project had six main objectives :

- 1.0 Initiate and complete hiring process for all new AVO staff members as soon as possible in the work flow cycle
- 2.0 Produce an initial Web presence and intranet capabilities for project-wide and community communication
- 3.0 Establish AVO Science Working Group and first pass assessments of critical science cases for prototypes
- 4.0 Define and implement prototype interoperability interfaces for first year tests
- 5.0 Define and commission hardware and software components for GRID, Storage and Database benchmarking activities
- 6.0 Produce a demonstration of prototype capabilities at +12 months in drawing on all work areas in coordination with similar international activities through the International Virtual Observatory Alliance

1.2 Results

All of these objectives have been either totally or mostly met within this reporting period. The AVO contribution to the definition, development and deployment of the first new international data standard for Virtual Observatories (VOtable), it's foundation role in the creation of the International Virtual Observatory Alliance (IVOA) and its successful development of VO interoperability and tool prototypes are the highlights of the first year.

1.3 Project Manager Information

The project has seen a shortfall in its planned manpower and associated costs for two principal reasons. Firstly, advanced funds from the EC did not arrive until four months after the project start date and secondly, the acquisition of some skills proved more difficult than expected from the IT and scientific/technical marketplace. Despite this shortfall, the project has succeeded in meeting the large majority of its year one objectives and has produced all foreseen deliverables. Planning for year 2 will take into account carryovers. The full planned manpower complement for the AVO project should be in place by Q2 2003.

2.0 Scientific and technical performance

2.1 Summary of project objectives for year 1

The specific project objectives for AVO in the first year were as follows:

- Initiate and complete hiring process for all new AVO staff members as soon as possible in the work flow cycle
- Produce an initial Web presence and intranet capabilities for project-wide and community communication
- Establish AVO Science Working Group and first pass assessments of critical science cases for prototypes
- Define and implement prototype interoperability interfaces for first year tests
- Define and commission hardware and software components for GRID, Storage and Database benchmarking activities
- Produce a demonstration of prototype capabilities at +12 months in drawing on all work areas in coordination with similar international activities through the International Virtual Observatory Alliance

Project work programs were verified and initiated at the first AVO Project Meeting held in Edinburgh on 15 November 2001. The minutes of this meeting (and all other AVO project meetings) can be found at <http://www.euro-vo.org/twiki/bin/view/Avo/ReportsAndMinutes>. The AVO work program was adopted and Work Area Managers assigned as follows:

- Work Area 0: Program Management - manager: P.Quinn (ESO)
 - Work-package 0.1 – Program Management
 - Work-package 0.2 – AVO Phase B definition
- Work Area 1: Science – manager: P.Benvenuti (STECF)
 - Work-package 1.1 – AVO SRM definition
 - Work-package 1.2 – AVO Science Requirements
 - Work-package 1.3 – Pilot implementations
- Work Area 2: Interoperability – manager: F.Genova (CDS)
 - Work-package 2.1 – Archive inclusion
 - Work-package 2.2 – Test evaluations
 - Work-package 2.3 – New functionality
 - Work-package 2.4 – Evaluation of tools
- Work Area 3: Technology – manager: A.Lawrence (U.Edinburgh)
 - Work-package 3.1 – Grid technologies
 - Work-package 3.2 – Storage and Computation
 - Work-package 3.3 – Database technology

The technical progress of the AVO work program will be described by major Work Area and work package as outlined above.

2.2 Technical Progress – Work Area 0 – Program Management

Work area 0 contains two work packages that define the overall management of the AVO work program and the preparation process of the Phase-B work program starting in 2005 (EURO-VO).

2.2.1 Program Management – WP 0.1

The main activities of WP0.1 in the first year of the AVO program can be summarized as

- Oversight of project-wide recruitment status plus the specific recruitment of a senior AVO systems engineer/architect
- Oversight and management of EC funds receipt and distribution. The initial advance of 786,541 € from the EC was distributed to partner organizations on 4 March 2002.
- Organization of project-wide meetings to coordinate and monitor work activities with particular emphasis on preparation of AVO technology and capabilities demonstrations. Project meetings were held in November 2001 (Edinburgh), April 2002 (Paris), September 2002 (Munich) and December 2002 (Cambridge). Full minutes of these meetings, with associated documents and actions are available at <http://www.euro-vo.org/twiki/bin/view/Avo/ReportsAndMinutes>.
- Interface to other international VO efforts (e.g. NVO) for the purposes of collaborative and coordinated actions leading to VO capabilities on the international scale. The International Virtual Observatory alliance was formed in June 2002 following a joint action by AVO, ASTROGRID and NVO. It now contains 9 member projects which hold joint coordination meetings on a regular basis. An international roadmap for VO development has also been drafted and is available at <http://www.ivoa.net>
- Coordination of AVO efforts with projects in the GRID community through AVO membership of the GRIDSTART consortium (<http://www.gridstart.org>) as well as the EIROforum Grid Group (<http://www.eiroforum.org>) .
- Development and maintenance of the AVO web pages at <http://www.euro-vo.org>.
- Design, development and deployment of AVO PR material with the assistance of the ESO and ES/STECF PR staff based at ESO headquarters in Munich. Two press releases were prepared and distributed in 2001/2002 (at <http://www.eso.org/outreach/press-rel/pr-2001/pr-26-01.html> and <http://www.euro-vo.org>) together with a 13 minutes video on the AVO project (at <http://www.euro-vo.org>) .

2.2.2 Phase B Plan – WP 0.2

Most of the major activities in this work-package will take place in the last year of the work program. However, responding to an opportunity to submit expressions of interest in programs under FP6, AVO submitted an IoE for AVO Phase B (EURO-VO) as an Integrated Project entitled Enabling Virtual Observatory for Europe (EVOE) which can be found at <http://www.euro-vo.org/> .

2.2A Technical progress - Work Area 1 – Science

2.2A.1 Definition of the AVO Science Reference Mission- WP 1.1

This work package aims at defining the Science goals against which the AVO scientific impact can be measured.

2.2A.1.1 Appointment of the AVO Science Working Group - WP 1.1.1

An invitation to submit a letter of interest in being member of the AVO Science Working Group was distributed to the astronomical community at large. The distribution was based on the ST-ECF Newsletter distribution list which contains more than 3000 addresses. About 50 expressions of interest were received. It was decided to appoint 31 members for the AVO SWG proper: 23 of them were selected from those who expressed interest, 8 were the members of the Astrovirtel Selection Panel. Given the wide interest, it was also decided to appoint all the remaining interested scientists in an AVO SWG “at large”. The latter will be kept fully informed about the development of the AVO Project and they will be invited to express their opinion and submit their suggestions. However, differently from the AVO SWG proper, no financial support for participation in meetings will be provided. The Terms of Reference of the SWG and the list of the AVO SWG members is appended (Appendix A).

During the 1st year the SWG met two times, on February 7th and June 12th at ESO, Garching

2.2A.1.2 Critical analysis of ASTROVIRTEL-type proposals.- WP 1.1.2

An analysis of the scientific requirements for the Astrovirtel proposals (Cycle 1 and 2) and for the GOODS large programme were analyzed as a preparation and base for discussion for the first meeting of the SWG.

2.2A.1.3 Preparation and issue of “fake” AVO Call for Proposal - WP 1.1.3

No activity

2.2A.2 Definition of the AVO Scientific requirements - WP 1.2

This work package aims at defining the scientific requirements for the implementation of the AVO. It concerns the type of data, their quality, their level of description and the requirements for high-level algorithms and software procedures. Actions 1 and 2 have strong interfaces with TBD actions in WPs 2.1, 2.2 and 2.3 of the WA 2 - Interoperability

2.2A.2.1 Definition of the type of data and requirements for their description (from a scientific use point of view) - WP 1.2.1

The characterization of the data that will constitute the AVO multiwavelength database was discussed during the first meeting of the SWG. It was decided to take a pragmatic approach and use the data of the Pilot Implementation as test for a more general definition. It was noted that a general discussion about “data ontology” was also initiated within the US NVO Project.

2.2A.2.2 Definition of quantifiable Quality Assurance criteria - WP 1.2.2

The following “elements” of the data quality were introduced and discussed:

- astrometry
- photometric quality
- spectral extraction
- psf/image quality
- instrumental properties
- links to catalogues and published data

Concerning astrometry, it was concurred that AVO should define a standard procedure (or a toolbox) for solving the “astrometric interoperability” issue among different archives, possibly based on the experience of cross-identification of objects in different archives (e.g. Class-X for the identification of X-ray sources).

The importance of a “standard” description of the photometric characteristics of the data was also addressed. To start with, the actual band-pass of the instrument should be linked to the data in tabular form. The VOTables, that are currently discussed by the AVO Interoperability Working Group, will offer the proper tool.

The increasing availability of multi-object and objective prism/grism spectroscopic data is posing the issue of how these data should be extracted and presented within the AVO. It was concurred that an automatic spectral extraction capability should be available. Its scope of applicability and its limitations should be clearly indicated to the user.

The requirement for a link between the data and the existing relevant literature was stressed. It was noted that there is already an extensive experience on the matter (e.g. at CDS, the ISO Archive, etc.) and AVO should capitalize on it.

Test the WP 1.2.1 and 1.2.2 definitions against the data set included in the AVO Phase A implementation WP 1.2.3

Action deferred after the 1st Demo (see below)

Definition of the Science requirements for high-level algorithms and procedures - WP 1.2.4

A initial set of requirements for the visualization and analysis of the AVO data to be experimented during the 1st demo of the Pilot Implementation was defined.

2.2A.3 Pilot implementation of selected science cases - WP 1.3

This work package aims at implementing in a pilot fashion a few selected AVO science projects.

2.2A.3.1 Selection of the test cases (in coordination with WA 2 and WA 3) - WP 1.3.1

The SWG indicated that the 1st Pilot Implementation should aim at demonstrating the AVO capabilities on a genuine multiwavelength database, the latter quality being more important than the extension of the field of view. In order to obtain a rapid progress in the 1st implementation, it was recommended to contact the Investigators involved in the GOODS Programme and to negotiate the possibility of using the GOODS data as a test AVO case. The agreement has been reached and part of the GOODS data will be used for the 1st Demo.

Considering that the GOODS Project is mainly cosmological in its nature, the SWG recommended that, if feasible, other data sets, more oriented towards galactic and stellar astrophysics, should be also considered. The field of the Orion Nebula and the stellar population of the Magellanic Clouds were indicated as suitable candidates. They will not be part of the 1st Demo, but they will be considered for future implementation.

2.2A.3.2 Design and implementation of required algorithms and procedures - WP 1.3.2

The EIS (ESO Imaging Survey) Calibration Pipeline, which is used to calibrate the ESO GOODS frames, was analyzed for possible future use within AVO.

2.2A.3.3 Running the procedures and implement feed-back - WP 1.3.3

Being implemented for the 1st Demo.

2.2A.3.4 Critical discussion of results - WP 1.3.4

Action deferred.

2.2B Technical progress - Work Area 2 – Interoperability

One basic task of WA2 is to federate a set of representative, ground and space European archives from the AVO partners. WA2 first year milestone is to implement an interoperability prototype archive federation, the prototype tools being the CDS interoperability services, VizieR for data federation and Aladin for data integration. The aims for the prototype system are to:

- enable early science usage of Virtual Observatory-like tools and get user feedback;
- evaluate interoperability tools in terms of usability and function;
- drive the specification and development of new functionalities;
- provide a test-bed for new and evolving standards (UCDs, VOTable).

The prototype has been successfully implemented.

Another aim is to heighten awareness about interoperability among archive providers, and to identify difficulties. Using experience obtained in the development of the prototype we are compiling a set of basic interoperability recommendations for data providers to assist in implementing their data within virtual observatory interoperability systems.

A second basic task of WA2 is the study and definition of common, internationally agreed, data exchange standards and tools for interoperability. Common standards are the key for a truly international VO, since they allow for easy communication and data exchange between archives and services. This has also been very successful, with the implementation of the first standard of the Virtual Observatory, agreed upon at the international level, VOTable. Version 1.0 was released on April 15th, 2002, and has been largely used since then. Other standards proposed in the frame of AVO WA2 such as the Uniform Contents Descriptors (UCDs), or by the National Virtual Observatory team such as the Simple Image Access Protocol, are actively discussed.

Finally, preparation of the AVO science demonstration, in particular the GOODS demonstration, has been a major WA2 activity from Summer 2002: feasibility study, implementation of demonstration data in the services; development of new, demonstration-linked, functionalities; customisation of the services.

2.2B.1. Inclusion of archives in the interoperability system – WP 2.1

The VizieR catalogue Browser and the Aladin integration tool gather metadata about catalogues, data archives and image servers. Using this metadata, the interfaces provide access to catalogues, images and remote resources for browsing, downloading data and

visualization of images and catalogues in a single environment. A set of European archives, representative of a variety of techniques (space/ground based, images/spectra, wavelengths from X-rays to radio), have been federated in the VizieR system: the observation list has been included in VizieR, with a standardized description; links to individual records in the archive has been implemented when possible, and an update mechanism has been built for "living" catalogues such as a growing observation log.

Lists of observations and survey catalogues from ESO (VLT and EIS), ESA (ISO and XMM), UK (INT Wide Field archive, in addition to Supercosmos and APM-North implemented during the preparation of the AVO proposal), Jodrell Bank (MERLIN), have been implemented. Active links have been implemented to the ISO and MERLIN archives. Cross-identification of the list of ISO observations in SIMBAD is on-going, to test more advanced interoperability functionalities to and from the ISO archive. In addition, a preliminary discussion on the ESA Herschel mission has been held with scientists from the Institut d'Astrophysique Spatiale (Orsay), to assess future inclusion of the Herschel data in the system (in particular complex, extended objects).

The implementation of observatory logs in the system has been performed through a case by case discussion with the data holder, in particular to define the data to be accessed by the interoperability system, to optimise the contents of the observation logs and its description, and to deal with issues such as data access rights and proprietary periods, or maintenance and update mechanism. In some cases this process stimulates archive holders to review their archive exposure mechanisms. Lessons learned from archive implementation are systematically reviewed to produce a set of interoperability recommendations to archive providers. The basic requirements for implementation are the availability of direct http access to archive imaged, and that astrometry information is supplied in the FITS World Coordinate System. Emphasis is also placed on including uncertainties and errors on measurements when possible, and on the inclusion of auxiliary information such as filter transmission curves. Data rights and access are also key questions to be addressed by archive holders prior to interoperability implementation: typical questions include the date at which the observations becomes public, the status of the data (are they fully or partially public, and if yes when?), and delegation (i.e. with whom the observers choose to share their data?). User identification and authentication, studied in particular by AstroGrid, is one important topic in this context. These questions, which are of general interest for archive managers, have been also presented to the OPTICON European Network partner meetings, and discussed with the team in charge of the prototype archive of *Telescopio Nazionale Galileo* (TNG), with the *Institut de Radio Astronomie Millimétrique* (IRAM) and with the *Integral* archive scientist.

2.2B.2. Running of tests and evaluation of results – WP 2.2

Implementation of archives in the system, running of tests and discussions with data providers have been a driver for new developments in interoperability tools. For instance, as a result of MERLIN implementation, Aladin has been adapted to the display of radio images. The importance of developing contour plots of images, and to allow the possibility of making astrometric registration adjustments, was also recognized (see 2.3). In addition, complementary radio catalogues such as the Westerbork Northern Sky Survey (WENSS) have been included in VizieR, because they were identified as a helpful addition for data interpretation.

The first major tests will be the first AVO Scientific Demonstrations, foreseen for January and August 2003. The test case frame was defined by the AVO Science Working Group (WA1) in

June-July 2002, feasibility in the WA2 framework was studied during Summer 2002, and a first Work Breakdown was proposed in September, then finalized at the AVO Executive Meeting (September 10-11, 2002). The demonstrations will use image/catalogue display and overlay based on Aladin and Vizier. The GOODS demonstration requires several new developments, which are described in the next Section. The required data has been identified and is being progressively implemented in the Aladin image server. A first presentation of the demonstration will take place at a "pre-demonstration" meeting in Strasbourg (November 15, 2002). The Magellanic Cloud demonstration is a second priority for January 2002. A short demonstration aimed at stellar astronomers will nevertheless be prepared on the basis of the existing versions of Vizier and Aladin, taking advantage of all the improvements performed in the frame of the AVO project, in collaboration with M. Kontizas, member of the SWG (activity foreseen in November 2002 and May 2003).

2.2B.3. Implementation of new functionalities and standards – WP2.3

2.2B.3.1. New functionalities

As explained earlier, several new functionalities developed in Aladin during the first year of the AVO project were defined through the implementation and tests of archives in the interoperability prototype:

- adjustment of image display to radio images;
- astrometric registration adjustments for images alignment, based on common image features, with tweaking capabilities;
- a facility to generate, display and manipulate contour plots.

In addition, the possibility to combine registered images into a RGB colour composite, developed in the frame of another project, *Images Distribuées hétérogènes en Astronomie* (IDHA, funded by the French *Ministère de la Recherche*), has also been implemented and made available.

New capabilities are also developed for the GOODS demonstration:

- cut-out service available from the Aladin image server;
- more flexible usage of the Aladin plane stack, allowing the user to visualize and use groups and hierarchies of data;
- usage of UCDS to locate, recognize and extract tabular information;
- usage of UCDS to perform data conversion and comparison;
- usage of VOTable for data exchange to and from Aladin.

Finally, collaboration has been settled with the Indian Virtual Observatory Team at the *InterUniversity Centre for Astronomy and Astrophysics* (IUCAA, Pune), for the development of a versatile system for visualisation of tabular data, which will be included in Vizier and Aladin, and used in the AVO scientific demonstrations in January or August 2002 (depending on the availability schedule). A prototype has been developed, and the specification of the final version will be discussed in details in Pune during a visit of F. Ochsenbein (WA2) in November 2002.

2.2B.3.2. Standards and tools

Standards and metadata are essential for a truly interoperable international virtual observatory, and it is highly significant that the first common milestone of the International VO Alliance has been the implementation of VOTable, an XML standard to describe tabular

data. VOTable has been defined by an international consortium of authors, including several WA2 participants, with a very active discussion list, and leadership shared by AVO WA2 (F. Ochsenbein) and NVO (R. Williams). The document can be found at <http://cdsweb.u-strasbg.fr/doc/VOTable> and the discussion is archived at <http://archives.us-vo.org/VOTable/>. VOTable has been designed to take advantage of XML properties, and also to minimize the XML 'tagging overhead', using the property of tabular data where columns are assumed to be homogeneous in terms of their associated metadata. It is also designed to be compatible with existing FITS data (FITS is the generic standard for data exchange in astronomy), and allows FITS or BINARY data to be embedded in the document, or to be accessed remotely.

The AVO interoperability prototype is an excellent test-bed for proposed standards. VizieR has been updated to return VOTable-compliant output soon after VOTable V1.0 release in April 2002. A fast VOTable parser, able to deal with very large lists, will soon be made available. Aladin, which is already able to access information in XML-astrores format, will soon be capable of accessing and distributing VOTable documents, in particular for interaction with modules developed by the other Work Areas for the GOODS demonstration.

Another area in which WA2 is very active is the definition and implementation of Uniform Contents Descriptors (UCDs). Astronomical tables come from many different sources (catalogues, tables published in journals, surveys, lists of observations in archives) and cover all fields of astronomy. They are thus an excellent starting point to describe the semantics of astronomical information. The Uniform Contents Descriptors have been defined first in the frame of the *ESO-CDS data mining project*, by organising hierarchically the contents of individual table fields (columns) from the CDS catalogue collection (more than 3,000 catalogues with over 100,000 columns). A UCD is attached to each VizieR table column, by a semi-automated procedure, using the column label, description and unit. The UCDs are also included in the VOTable metadata. The usage of UCDs for catalogue selection, in addition to existing methods such as keywords, author names, ... is presently developed. UCDs can also be used, together with units, for data comparison and conversion. This will be implemented for the GOODS demonstration. A tool to access the UCD tree, using different query types, has been developed¹. Several actions are under way to evaluate UCDs in a wider context: a very encouraging check was recently performed with A. Szalay (SDSS/NVO), to match the 1,500 columns of the Sloan survey with the 1,300 UCDs – this also allowed the verification of the homogeneity of the catalogue contents, column names, units and descriptions; the usage of UCDs in radioastronomy has also been discussed in details with A. Richards. In addition, a recent proposal by G. Rixon, to reshape UCDs by implementing a more flexible 'atomic' structure, is being assessed.

The data model developed in the frame of the IDHA project is open for discussion in WA2 and at the international level (in particular with NVO/CfA and with D. Giaretta, RAL). The usage of UCDs in this model will be assessed in the coming months. A description of GOODS data in the frame of IDHA data model will be used in AVO science demonstration.

The use of the Web Service paradigm is rapidly growing in the VO community. It has been for instance adopted in the planning of AstroGrid. Several years ago, the CDS developed the GLU system (*Générateur de Liens Uniformes*), for ensuring efficient interoperability between its services by allowing usage of symbolic names instead of hard-coded URLs in data. The GLU system has functionalities such as browsing through the available resources, defining a 'clever' directory of resources (allowing e.g. queries to the participating services by data

types), managing links to on-line documentation, providing a test sequencer of URLs. It can moreover manage clones. The GLU Dictionary is a distributed dictionary, which is shared by all the partners, can be updated by registered participants (with authentication of the update sender), allows for definition of distribution domains and manages a hierarchical name space. This is a very early prototype allowing many of the VO required functions. One important action in the coming months is to assess which GLU functionalities are not (or not yet) provided in the Web Service framework (e.g. data conversion at the request level), and to define and implement the possible GLU evolution in the new context. A SOAP access to the GLU will for instance be developed.

Standards are a major topic for all VO projects, and they are discussed at the international level in the Interoperability Working Group, chaired by F. Genova, and with a very active participation of WA2. This Working Group was first proposed by the partners of the OPTICON European thematic network, and then extended to a wider international membership (USA, Canada, Australia) to provide a forum for discussion between the VO projects: the main goals are to circulate information among the participants, to discuss lessons learnt, to discuss and implement common standards, and to build a draft roadmap for development of VO standards. Three meetings were held in 2002: the first one, in Strasbourg (January 26-29, 2002), allowed detailed discussion of VOTable and built solid grounds for agreement. The second meeting, in Garching (June 12, 2002), allowed exchanging information about on-going projects. The third meeting, in Baltimore (October 17, 2002), allowed a detailed discussion of on-going developments, in particular the UCDs (WA2) and the Simple Image Access Protocol proposed by NVO. A report was also presented about an international effort, including the IDHA project among the major partners, to build convergence on data models in Astronomy.

2.2B.4 Evaluation of interoperability tools – WP2.4

This topic will be studied at a later stage of the project.

2.2C Technical progress - Work Area 3– Technology

The overall purpose of WA3 is to assess, develop, and deploy new technologies needed to construct a Virtual Observatory. These technologies are in three main areas - storage and compute technology, Grid technology, and database/datamining technology. In all these areas the technological background is evolving very rapidly, and application projects throughout science, and indeed business requirements, are facing very similar challenges. For this reason, we need to remain agile in our approach.

WA3 has been a success to date, with significant progress in assessment and testing of key technologies, and establishing relationships with other grid projects Europe wide. New recruitment into WA3 has been slow, but the existing staff have been very active from the start of the project, and AVO has benefitted indirectly from a larger pool of effort in the AstroGrid and NGAST projects. The existing staff are mostly scientists, whereas newly recruited staff are mostly professional software developers. Along with the rapidly evolving nature of the technological background, this has led to a slight change of emphasis in the work plan, in that we have taken a simplified attitude to benchmark design, have accelerated the technology assessment programme, and are now moving towards trial deployments as rapidly as possible.

Assessment of technology in the area of databases and storage/compute technology has been progressing well, with some very interesting results. Perhaps the most striking success however has been in assessment and testing of grid middleware, both from the academic

computer science side (*OGSA* etc) and from the commercial/W3C side (web services etc), and a subsequent involvement in interdisciplinary efforts to forge a merger between these approaches.

2.2C.1 Grid Technology - WP3.1

2.2C.1.1 Middleware

We have undertaken a thorough investigation of grid middleware technologies, which has led to an evolution of a forward vision. The work done here is summarised in a document originally written as part of the AstroGrid Phase A report, and which can be found at <http://wiki.astrogrid.org/bin/view/Astrogrid/RbGridTechnologyReport>. Here we summarise the main findings.

We investigated several grid middleware packages and related technologies, including *Globus*, *Condor*, *Storage Resource Broker*, and a commercial implementation from Sun called *Grid Engine*. *Condor* and *Grid Engine* were the most robust and reliable, but of limited usefulness to us, as they are aimed at computational grids, as opposed to the *data grid* structure we need. The most important package is *Globus*, as it was developing as the standard international toolkit for Grid applications. However it had clear limitations. The first is that it is a development project, not yet a real product, being hard to implement and use, and with many parts not working. The second major drawback is that data transfer is for flat files only, with no way to address structured databases.

We see the Virtual Observatory as primarily a *service grid*, i.e. a network of data centres which offer operations on datasets. This matches well onto the *web services* technology, which during the last year has emerged as a new industry standard. This involves data exchange in XML formats, sent in messages with SOAP wrappers, and with the data service specified in WSDL, and published to some kind of registry. This technology offers most of what we need for the VO, but there are problems. Firstly, standard web services are one-to-one whereas we need to compose services; secondly, XML is bulky, so we need a standardised way to link to binary data; and thirdly the standard emerging registry, UDDI, is for various reasons not suitable.

The *Globus* and Web Services worlds are now merging into the concept of *grid services*, to be implemented through a project called *OGSA* (Open Grid Services Architecture). Of particular importance for the VO is the sub-project to establish a Database Access Infrastructure (*OGSA-DAI*), which is a collaboration between the UK e-Science core programme and IBM Hursley. We have established a working relationship with the *OGSA-DAI* team.

Since September the effort in WP3.1 has shifted focus, and is now concentrated on test-deployments, firstly of the *Globus* toolkit, and also of web service technology, in collaboration with WA1 and WA2 as part of the January 2003 demonstrations. This involves adapting existing tools to work remotely with a distributed data set using XML/SOAP standards. We expect both to make a useable product, and so learn lessons about user requirements, but also to learn technological lessons.

2.2C.1.2 Network studies

Following initial research, it became clear that the necessary network monitoring benchmark tasks needed had already been written by the particle physics community for a variety of projects. We joined two key UK-based committees (CNAP and PPNCG) and requested addition of key astronomical sites across Europe to the monitoring list. Specific results have

not yet been analysed, but a general conclusion Europe wide is that in practice working bandwidth is not limited by fibre capacity, but largely by security bottlenecks and other end-point and router CPU issues. Meanwhile, as well as analysing the physical network, we need to decide how to assess the speed performance of grid infrastructure components across the network. Guy Rixon in Cambridge has written a draft document setting out a proposal of how to take this analysis forward. This document can be found at <http://www.euro-vo.org/twiki/bin/view/Avo/Work-packageThreeOne>.

2.2C.2 Storage/Compute Technology - WP3.2

At ESO, work has concentrated on continued development of the *NGAS* system. The concept is one of accumulating PC and IDE storage as a cluster with associated software so that storage and CPU are configurable and hot-swappable, while the system grows scaleably, and with CPU and storage maintained in balance. During this year we have established data check plugin capability. This plugin is executed in configurable intervals on each server, computes checksums of every file and compares the result with a value stored in the data base. Extended *NGAS* capabilities include transparent cloning and synchronization of data to another host somewhere on the network. All *NGAS* data is now treated on a file basis, i.e. the concept of master and replication disks has been dropped in favor of a very homogeneous management of multiple copies of the same file. Retrieval logic returns files preferably from the location closest to the requester. *NGAS* disks can be removed from the repository and recycled using the *NGAS* server. In the both cases the files registered on the disk are removed from the repository as well. Extended *NGAS* capabilities include transparent processing requests. Registered processing requests to any *NGAS* node are always carried out close to the data, i.e. on the host which holds the data.

At Jodrell Bank, work in WA3.2 has focussed on testing the performance of compute-intensive data reduction and analysis on the MERLIN archive with AIPS++ using a large Beowulf cluster (with 182 nodes). A key aim in federating radio data with other wavebands is to be able to derive images on demand and on the fly from fringe data, but this is computationally challenging. This system seems now to be working well, and the next step is to make it work across the network within Globus.

A variety of other machines are being installed at tested at various sites. For example in Edinburgh duplicate versions of the SuperCOSMOS archive are being set up on a monolithic RAID array, on a Windows cluster running SQL server, and on a 16 processor SMP machine running DB2 kindly donated by IBM.

2.2C.3 Database Technology - WP3.3

A thorough investigation of the issues involved in data mining, and performance tests of specific DBMS, has been carried out by AstroGrid staff, and is described in the relevant chapter of the AstroGrid Phase A report. This can be found at <http://wiki.astrogrid.org/bin/view/Astrogrid/RbDataminingTechnologyReport>. We have evaluated DB2, MySQL, Oracle, Postgres, and SQL Server. All had fairly similar speed performance to within the uncertainties of different platforms, tunings, and so on. There were some clear worries that holds lessons for how to implement networked astronomical archives. All DBMS supported indexed operations efficiently, but were several times slower than expected on sequential scans. None of the DBMS had a good way of importing bulk data from or exporting to binary files such as images. Quite a few of the kind of queries that astronomers want to do are not easily expressible in standard SQL. Moreover, none of the DBMS implement full standard SQL92, so that many of the benchmark tests had to be adjusted for each separate DBMS. These last two points together (non-standard queries, and

non-compliant implementation) suggest that we need to develop some kind of standard Astronomical Query Language (AQL), with a "driver" for each specific DBMS.

Further performance tests were run by AVO staff at TeraPix, concentrating on comparing an object oriented DBMS (Objectivity) with a relational one (MySQL). Unlike the AstroGrid tests which were very general, the TeraPix staff made more detailed tests of the sensitivity of the DBMS to various tuneable parameters. These results have been presented at the recent SPIE conference.

2.3 Planned Activities and Actual Work

2.3.1 Work-package 0.1: Program Management

Planned Activity	Completed?	Comments
Staff Recruitment	Mostly	<ul style="list-style-type: none"> • Eight of nine positions filled successfully • AVO Scientist position - no candidate found despite advertising and offers • position being filled temporarily by seconded ESO and Astrogrid staff • recruitment continues
Establish Web Presence	Fully	
Initiate international VO project links	Fully	

2.3.2 Work-package 0.2: Phase B Plan

Planned Activity	Completed?	Comments
Respond to FP6 Expression of Interest	Fully	

2.3.3 Work-package 1.1: Definition of the AVO Science Reference Mission

Planned Activity	Completed?	Comments
Appointment of the AVO Science Working Group	Fully	
Critical analysis of ASTROVIRTEL-type proposals	Fully	

2.3.4 Work-package 1.2: Definition of the AVO Scientific requirements

Planned Activity	Completed?	Comments
Definition of the type of data and	Fully	

requirements for their description		
Definition of quantifiable Quality Assurance criteria	Mostly	<ul style="list-style-type: none"> • Discussion ongoing • Further refinement following AVO demonstrations in January 2003

2.3.5 Work-package 1.3: Pilot implementation of selected science cases

Planned Activity	Completed?	Comments
Selection of the test cases	Fully	

2.3.6 Work-package 2.1: Inclusion of archives in the interoperability system

Planned Activity	Completed?	Comments
A representative set of European archives federated in the Vizier system	Fully	
Observation list included in Vizier, with a standardized description	Fully	
Links to individual archive records implemented where possible	Fully	
Update mechanism built for "living" catalogues	Fully	

2.3.7 Work-package 2.2: Running of tests and evaluation of results

Planned Activity	Completed?	Comments
Preparation for first major tests at the AVO Scientific Demonstrations in January 2003	Fully	

2.3.8 Work-package 2.3: Implementation of new functionalities and standards

Planned Activity	Completed?	Comments
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New functionalities developed	Fully	<ul style="list-style-type: none"> - radio images; - astrometric registration; - contour plots. - cut-out service - usage of UCDS - usage of VOTable
Implementation of VOTable 1.0	Fully	

2.3.9 Work-package 3.1: Grid Technology

Planned Activity	Completed?	Comments
Initial investigation of grid middleware technologies	Fully	
Initial study of networking requirements	Fully	
Development of Web services prototype for AVO demonstrations (ACE)	Fully	

2.3.10 Work-package 3.2 Storage/Compute Technology

Planned Activity	Completed?	Comments
Development and evaluation of ESO NGAS system	Partly	<ul style="list-style-type: none"> • This work is ongoing and will continue for the duration of the AVO work program with updates as operational experience and hardware capabilities improve • This work-package will be reviewed in early year 2
Evaluation of Beowulf cluster at JBO for radio astronomy computing	Fully	

2.3.11 Work-package 3.3: Database Technology

Planned Activity	Completed?	Comments
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Evaluation of DB2, MySQL, Oracle, Postgres, and SQL Server	Fully	
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2.4 Planned Activities for Year 2

The activities planned for Year 2 are consistent with the work program contained in the description of work for the AVO Phase-A contract (HPRI-CT-2001-50030).

2.4.1 Work Area 0 Activities

- Ongoing program management including regular project meetings
- Coordination with international efforts through IVOA
- Coordination with EC Grid projects through GRIDSTART and EIROforum
- Completion of AVO staffing
- Preparation of FP6 proposals in response to 2003 calls
- System Engineering/Management of AVO international demonstrations at IAU Sydney in July

2.4.2 Work Area 1 Activities

- Regular Science Working Group meetings
- Further definition of science requirements for implementation in annual demonstrations of new capabilities
- Fully discussion and definition of data quality metrics and assessment process in coordination with IVOA discussions on these topics
- Preparation for implementation of trial VO science cases in year 3

2.4.3 Work Area 2 Activities

- Regular interoperability meetings in coordination with IVOA effort with particular focus on issues concerning UCDS, data models and resource registry
- Assessment and expansion of new functionalities to meet needs of coordinated demonstrations and trial science cases
- Further development of new standards for data access (e.g. UCDS, SIA and VOTable)
- Trial execution of science cases

2.4.4 Work Area 3 Activities

- Implementation of middleware choices for trial datagrid testbed in coordination with AVO demo for year 2
- Demonstration of typical data rates and compute performance on choice hardware and software platforms
- Demonstration of planned performance needs on choice database engine

3.0 List of Deliverables

The following table details the status of the project deliverables for the first twelve months according to the work program as specified in the contract. Associated or complementary products and reports are also listed.

Work-package	Deliverable	Comments
WP0.1	Annual report	DELIVERED: This report
WP0.2	No scheduled deliverable	
WP1.1	AVO Science Reference Mission Document	DELIVERED: <ul style="list-style-type: none"> - SWG terms of reference DONE http://www.euro-vo.org/twiki/bin/view/Avo/SwgReports - SWG Science Case Definition DONE http://www.euro-vo.org/twiki/bin/view/Avo/SwgReports
WP1.2	No scheduled deliverable	
WP1.3	No scheduled deliverable	
WP 2.1	Working prototype	DELIVERED <ul style="list-style-type: none"> • Within public version of Vizier and Aladin from CDS http://cdsweb.u-strasbg.fr/
WP 2.2	No scheduled deliverable	
WP 2.3	No scheduled deliverable	
WP 2.4	No scheduled deliverable	
WP3.1	Grid Evaluation	DELIVERED http://wiki.astrogrid.org/bin/view/Astrogrid/RbGridTechnologyReport
WP3.2	Storage/Computer Evaluation	PARTIAL - POSPONED <ul style="list-style-type: none"> - due to the late availability of manpower and funds and the rapid movement in the market place of available hardware and software, these evaluations have been moved to year 2, closer to large scale production tests - Storage management development reports available under ESO NGAST project at http://archive.eso.org/NGAST/
WP3.3	Database Technology Evaluation	DELIVERED http://wiki.astrogrid.org/bin/view/Astrogrid/RbDataminingTechnologyReport

4.0 Exploitation and dissemination of results

The work of the AVO project team has been widely reported and presented during the past twelve months. The following section summarizes these dissemination activities. A comprehensive list of AVO publications, presentations and related articles can be found at <http://www.euro-vo.org/twiki/bin/view/Avo/AvoPubArts> and <http://www.euro-vo.org/>.

4.1 Conferences:

The principal event of the first twelve months was an international meeting held in Munich from June 10-14 2002 under the joint sponsorship of ESO, ESA, NASA and NSF. The meeting entitled Towards an International Virtual Observatory brought together more than 160 leading astronomers, scientists, engineers and representatives of major technology organizations to discuss the scientific drivers and technologies necessary for virtual observatories. The conference was a major success and was reported on by Nature “**Astronomers give virtual observatory a real future**” *Nature* **417**, 777 (20 Jun 2002) News. The home page for the conference can be found at <http://www.eso.org/vo2002> and contains links to many of the presentations on AVO and related work.

The AVO project was also represented at an international meeting held as part of the SPIE Meeting on Astronomical Telescopes and Instrumentation held in Hawaii from August 22-28 2003. <http://spie.org/Conferences/programs/02/as/>. A summary paper on the AVO was presented: “The Astrophysical Virtual Observatory (AVO): A Progress Report”, P.Quinn, P.Benvenuti, P.Diamond, F.Genova, A.Lawrence, Y.Mellier. A further paper, “AVO Interoperability Demonstration” was also presented, the list of authors include F. Genova and P. Didelon.

4.2 International Press:

The AVO project and the international VO effort working in coordination under the International Virtual Observatory Alliance was featured in a major news feature by Nature in November 2002.

Astronomy: The heavens at your fingertips
Nature **420**, 262 - 264 (21 Nov 2002) News Feature

4.3 Presentations and Papers:

The following is a list of AVO papers and associated publications given by AVO team members in the last twelve months.

Toward and AVO Interoperability Prototype, M.G. Allen, F. Genova, C. Arviset, S. Derriere, P. Didelon, S.T. Garrington, R.G. Mann, A. Micol, F. Ochsenbein, A.M.S. Richards, G.T. Rixon, A. Salama, A. Wicenc, C. Benoist, J.R. Lewis, *Toward an International Virtual Observatory*, Garching, June 10-14, 2002

VOTable: Tabular data for the Virtual Observatory, F. Ochsenbein, R.D. Williams, C. Davenhall, D. Durand, P. Fernique, R.J. Hanisch, D. Giaretta, T.A. McGlynn, A.S. Szalay, A. Wicenc, *Toward an International Virtual Observatory*, Garching, June 10-14, 2002

Data Mining facility for the VO, S. Derriere, F. Ochsenbein, P. Ortiz, M.G. Allen, T. Boch, *Toward an International Virtual Observatory*, Garching, June 10-14, 2002

Archive interoperability in the Virtual Observatory, F. Genova, *Exploiting the ISO data archive: Infrared astronomy in the internet age*, Siguenza, June 2002

AVO interoperability demonstration, F. Genova, M.G. Allen, F. Ochsenbein, C. Arviset, A. Micol, R.G. Mann, G.T. Rixon, P. Didelon, S.T. Garrington, A.M.S. Richards, A. Wicenec, *SPIE Conference on Astronomical Telescopes and Instrumentation*, Waikoloa, August 2002

Interoperability of archives in the Virtual Observatory, F. Genova, G.T. Rixon, F. Ochsenbein, C.G. Page, *SPIE Conference on Astronomical Telescopes and Instrumentation*, Waikoloa, August 2002

Metadata for the VO: the case of UCDS, S. Derriere, F. Ochsenbein, T. Boch, *Astronomical Data Analysis Software & Systems XII*, Baltimore, October 2002

Towards an AVO interoperability prototype, M.G. Allen, F. Genova, F. Ochsenbein, S. Derriere, C. Arviset, P. Didelon, R.G. Mann, A. Micol, A.M.S. Richards, G.T. Rixon, A. Wicenec, M. Dolensky, *Astronomical Data Analysis Software & Systems XII*, Baltimore, October 2002

Genova, P. Benvenuti, D.S. De Young, R.J. Hanisch, A. Lawrence, T. Linde, P.J. Quinn, A.S. Szalay, N.A. Walton, R.D. Williams, *American Astronomical Society 200th meeting*, Albuquerque, June 2002

5.0 Management and coordination aspects

5.1 Project Communications

Communications within the AVO project consists of four main components:

5.1.1 Project meetings

These meetings take place approximately quarterly and involve all work area and work package managers as well as staff reporting on work area activities. Meetings were held on 15 November 2001 in Edinburgh, 2 April 2002 in Paris and 10 September in Munich. Minutes and actions associated with these three project meetings, as well as related documents, can be found on the AVO web site at <http://www.euro-vo.org/twiki/bin/view/Avo/AvoEvents> and <http://www.euro-vo.org/twiki/bin/view/Avo/ReportsAndMinutes>. The final quarter meeting for 2002 was covered by a technical meeting at Cambridge on 16 December and informal meetings in preparation for the January 2003 AVO demonstrations.

5.1.2 Technical meetings

Meetings on specific technical topics within a work area or across work areas are held on an adhoc basis as project needs dictate. Several meetings on interoperability issues and technical aspects of the AVO demonstrations for January 2003 were held in 2002. Reports and minutes can be located at <http://www.euro-vo.org/twiki/bin/view/Avo/AvoEvents>.

5.1.3 Intranet

The AVO project has followed the lead of the ASTROGRID consortium and established an internet communication system based on technology known as TWIKI. This has proved to be extremely effective at facilitating and promoting project communications. The system now acts as an extensive historian of project evolution and a repository of project documents and products. The main entrance for the AVO intranet is <http://www.euro-vo.org/twiki/bin/view/Avo/WebHome>.

5.1.4 Telephone Conferencing

AVO makes extensive use of telephone conferencing for AVO Executive meetings (involving the six representatives of the AVO partners) and for communications with other VO projects through the International Virtual Observatory Alliance. The IVOA tele-cons frequently involve project representatives from a large number of time zones (US east and west coast, UK, France, Germany, Russia, India, China, Japan and Australia). The IVOA was founded from these tele-cons which began in December 2001. Minutes of the IVOA tele-cons can be found on the IVOA web site (currently developed and maintained by AVO) at <http://www.ivoa.net/twiki/bin/view/IVOA/IvoaRepMin>.

The following lists the travels and meetings attended by each participant:

Participant 1 and Co-ordinator: ESO

- No travels charged to EC.

Participant 2: ESA

1. AVO collaboration with Astrogrid, Leicester 11th January 2002.
Planning of Astrogrid involvement as Grid technology provider within AVO project
2. AVO Interoperability Meeting, Strasbourg 28-29th January 2002.
Discussion of meta data standards and exchange format within Virtual Observatory.
3. AVO Executive Meeting, Paris 2nd April 2002.
AVO management meeting with 1st WP progress reports and detailed planning of 1st year activities.
4. Astrogrid Project Meeting, London 26-27 June 2002
Astrogrid project meeting with participation from various other invited grid projects.
5. AVO interoperability Meeting, Strasbourg 30th September – 1st October 2002
Interoperability meeting with the focus on data modeling and meta data concepts

Participant 3: ULPS.CDS.OAS

1. AVO Project Kick-off meeting, Edinburgh 15 November 2001, including discussions with AstroGrid partner about data for WA2 prototype (November 14, 2001)
2. Fourth GRID data projects conference, Paris 8 March 2002,
Information about GRID (for collaboration with WA3)
3. Discussion with T. Contini, Strasbourg, 12-14 March 2002
Evaluation of the usage of ISO data to test advanced VO functionalities (T. Contini was the CDS expert on this data before leaving for Toulouse)
4. XML/WEB Service/OGSA Workshops, Edinburgh 18-21 March 2002.
Information about Web Services (WA3 collaboration)
5. AVO Project Executive meeting, Paris 2 May 2002
6. Meeting with French experts of Web Services from the LORIA (Laboratoire Lorrain de recherche en informatique et ses applications) (for collaboration with WA3): SOAP day Strasbourg, 29 April 2002
7. AVO Project Executive meeting, Munich 10 September 2002
8. AVO Technical Meeting, ESO Garching 11 September 2002 – Design of documents for AVO prototype discussed. Assessment of the Work Breakdown
9. Evaluation of advanced VO functionalities, Paris 6-14 October 2002.
Discussion about data from the Herschelsatellite (extended objects)

10. AVO WA2 meeting, Strasbourg 30 September-1 October 2002.
Status of WA2 developments (interoperability prototype, AVO demonstration preparation) and discussion on VO standards
11. Scientific Data Mining, Integration and visualization Workshops, Edinburgh 24 –25 October.
Information about advanced IT tools (WA3 collaboration)

Participant 4: UEDIN

1. Astrogrid Progress meeting, Leicester 19-20 August 2002
2. AVO Demonstration Meeting, Cambridge 22 August 2002
3. AVO Demonstration preparation meeting, Cambridge 5-9 September 2002
4. AVO Project Executive meeting, Munich 10 September 2002
5. AVO Technical Meeting, ESO Garching 11 September 2002 – Design of documents for AVO prototype discussed. Assessment of the Work Breakdown

Participant 5: CNRS / IAP

1. Towards an IVO Conference, Garching 17-21 June 2002
2. AVO Meeting, Garching 8-12 July 2002
Meeting to discuss definition of input catalogue specifications for astronomical calibration.
3. AVO Meeting, Garching 5 – 9 August 2002
Meeting to discuss implementation and validation of photometric calibration call programme.
4. SPIE Conference, Hawaii, USA 19 August – 8 September 2002 **** NOT TO BE FUNDED BY EC MONIES**.**
5. SPIE Conference, Hawaii, USA 5-29 August 2002**** NOT TO BE FUNDED BY EC MONIES**.**
6. AVO Meeting, Garching, 10-11 September 2002
AVO Executive meeting and preparation for Demo
7. AVO Meeting, Garching, 16-20 September 2002
Meeting to discuss implementation and validation of photometric calibration call programme.
8. AVO Meeting, Strasbourg 29 September – 1 October 2002
Meeting to discuss definition of metadata for Terapix from the CDS

Participant 6: JBO

1. AVO Executive Meeting, Paris 2nd April 2002.
AVO management meeting with 1st WP progress reports and detailed planning of 1st year activities.
2. UN National Astronomy Meeting including VO events, Bristol 9-12 April 2002
3. Towards an IVO conference, Garching 10-14 June 2002
4. Ontology Tutorial, Edinburgh 25 July 2002
5. AstroGrid meeting, Leicester 19-20 August 2002
6. AVO demo meeting, Cambridge 22 August 2002
7. AVO Meeting, Garching, 10-11 September 2002
AVO Executive meeting and preparation for Demo
8. AVO Meeting, Strasbourg 29 September – 1 October 2002
Meeting to discuss definition of metadata for Terapix from the CDS
9. DataGrid conference, Edinburgh 24-25 October 2002
10. SKA (Square Kilometre Array) workshop, Oxford 7 October 2002

5.2 Manpower allocation and utilization

The following section details the planned and actual allocation of human resources to different work areas from the six partner organizations of AVO. The total allocation of manpower in the first year of the project fell short of planning as detailed in the contract for two reasons. Firstly, the advance of funds from the EC did not arrive until late February 2002 whereas the project commenced on 1 November 2001 as planned. This four month period effectively accounts for a loss of 32.4 person months of manpower across the 9 new positions planned for EC funds. Secondly, it has proved to be difficult to find many of the skills we required in the competitive IT and scientific/technical marketplace. Several key engineering positions could not be filled until late Q3 and early Q4 of 2002. Despite several attempts, the project is still seeking to fill the last AVO position for the AVO scientists. The AVO scientist duties have been spread within the project and we have solicited the assistance of ESO and ESA staff to supplement this shortfall. The project is confident of filling this position in Q1 of 2003.

Annex 1 of the contract (DESCRIPTION OF WORK) contains the detailed planned distribution of manpower for each work area and by institution. Those planning numbers for the entire duration of the project are summarized in the following tables compared with the actual (following project kick-off fine tuning) numbers for year 1 and the submitted cost statements for manpower.

Work Area	ANNEX 1 (person months)	Actual Year 1 (person months)
Work Area O	35.8	9.4
Work Area 1	138.8	25.1
Work Area 2	220	40.8
Work Area 3	178	50.2
TOTALS	572.6	125.5

In the following table the person hours listed in the cost statements (column 4) are exactly equivalent to the reported person months for year 1 (column 3) when each organizations FTE accounting procedures are taken into account.

Contractor	ANNEX 1 (person months)	Actual Year 1 (person months)	Cost statements Year 1 (person hours)	Cost statements Year 1 Coordination (person hours)
1. ESO.DMD	115.2	22.2	3799	234
2. ST-ECF	68.7	15.3	2432	
3. UEDIN.IA*	144.0	30	619*	
4. CNRS.CDS.OAS/ ULPS.CDS.OAS	108.0	27.2	4327	
5. CNRS.IAP	64.7	12.9	2064	
6. UMNC.DP.A.JBO*	72.0	17.9	945*	
Overall Total	572.6	125.5	14186	234

* UEDIN and UMNC DP.A. JBO cost statements only list EC funded staff

5.3 Project Budgets

The budgetary details for each AVO partner is presented as Cost Statement Summary forms contained in Appendix B. The following table summarizes the expenditure in Euros for the major cost categories.

Contractors	Personnel	Durable Equipment	Travel and subsistence	Consumables	Coordination	Total
ESO.DMD*	101,702	5,327	0	0	8050	115,079
STECF	68,522	0	6,748	0		75,270
UEDIN.IA	22,696	0	1,778	1396		25,870
CNRS.CDS.OAS/ ULPS.CDS.OAS	127,237	0	12,259	0		139,496
CNRS.IAP	49,896	1,807	6435			58,138
UMNC.DP.A.JBO	24,703	1,690	5,744			32,137
Year 1 TOTAL	394,756	8,824	32,964	1396	8050	445,990
Planned TOTAL whole project	2,017,967	252,100	154,900	0	24,150	2,449,117

The shortfall in the personnel area compared to the planned personnel funds for year 1 is consistent with the average shortfall expected in manpower from the delay of first year funds availability and the acquisition problems with the AVO technical position. The reduction of hardware purchases was a planned activity due to rapid movement in the IT

hardware market with respect to file and database servers and overall uncertainties in the requirements for VO servers given the lack of technical experience in some areas that resulted from the late arrival of AVO staff. These hardware funds have been transferred to the planned expenditure for years 2. The variation in cost for travel is again consistent with the overall late arrival of AVO staff.

5.4 Attribution of tasks

The specific attribution of costs for posts is covered by the identification of work areas in the table from Section 5.1 and the individual work area reports contained in Section 2 together with details contained in the Cost Statements for each partner.

6 Appendices

Appendix A – Terms of Reference and membership of the AVO SWG.

The AVO Science Working Group – Terms of reference

1. The AVO SWG is composed of **principal members** and **members at large**. Principal members are invited to actively participate in the meetings of the SWG. The participation in the meetings is financially supported by the AVO Project. Members at large are those who responded positively to the invitation to participate in the AVO science activities, but could not be selected in order to keep the size of the SWG within financial and efficiency boundaries. Members at large will be kept informed about the work of the SWG and will be invited to provide comments and input by electronic means.
2. The AVO SWG is chaired by the AVO Science Area Coordinator.
3. The AVO SWG will advise the Project in the following areas:
 - a. Definition of the AVO Science Reference Mission or, alternatively, the Science goals that the AVO Phase A has to achieve in order to be considered successful.
 - b. Scientific quality of the archived data and quantitative methods to describe it in the different wavelength ranges. Minimum acceptable level of scientific quality for AVO data.
 - c. Critical analysis of the scientific quality of the existing on-line archives. Suggestions for improvements.
 - d. Scientific accountability of AVO and of the federated archives. Traceability and acknowledgement of scientific decisions within AVO.
 - e. Data analysis methods and tools for the AVO data.
 - f. Progress review of AVO
 - g. Scientific requirements for the AVO Phase B (AVO full implementation). AVO Science Operation concepts.
4. The AVO will maintain web pages with the minutes and resolutions of the SWG. Work areas, restricted to the SWG members, will also be available, if needed.

The AVO SWG membership will last for the duration of the Phase A Project.

AVO SWG – Principal Members

Name	Institute
Lofti BEN JAFFEL	Institute d’Astrophysique, Paris
Andrea CIMATTI	Arcetri Observatory, Florence
Luiz DA COSTA	ESO Garching
Richard DE GRIJS	Institute of Astronomy, Cambridge
Daniel EGRET	Observatoire de Strasbourg
Giuseppina FABBIANO	Center for Astrophysics, Cambridge, MA
Gerry GILMORE	Institute of Astronomy, Cambridge
Ana I. GOMEZ DE CASTRO	Universidad Complutense de Madrid
Krzysztof GORSKI	ESO Garching
Preben GROSBØL	ESO Garching
Bob HANISCH	ST ScI, Baltimore
Ulrich HOPP	Universitäts-Sternwarte Munich
Florian KERBER	ST-ECF
Mary KONTIZAS	University of Athens
Patrick LEAHY	Jodrell Bank, Manchester
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Appendix B – Cost Statements