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EXECUTIVE SUMMARY

WP4 is, for some of its activities, dedicated to a coordination of the implementation of the new large infrastructures to better fulfil the expectations of the European astronomical community. Among the actions, important efforts are developed towards a sustainable virtual observatory establishment. In this report we propose the main actions towards possible agreement between the national funding agencies to implement the VO in a permanent way and we analyse the Technical Sustainability Report provided by CoSADIE as the main input for the European Coordination for the future Euro-VO.

1. INTRODUCTION

The importance of 'open data' and e-Infrastructures continues to be recognized by high-level European and International bodies. Governments and funding agencies are promoting 'open data' policies requiring that data obtained with public funds be, in general, publically accessible. The G8 Science Ministers have stated a set of principles for open scientific research data emphasizing that data should be 'easily discoverable, accessible, assessable, intelligible, useable and wherever possible interoperable to specific quality standards', which is in line with the recommendations of the ASTRONET Roadmap.

The architecture of the Virtual Observatory (VO) system is now well established with a set of core standards. It has progressed from an early deployment phase in 2008 to an operational phase, whereby the basic interoperability building blocks have been defined and are being implemented. The relevance of the VO to European data centers is well established via the 2008 and 2010 Data Centre Census (conducted by EuroVO-DCA and EuroVO-AIDA). This provided a snapshot of European astronomy data centers, identifying 69 data centers across Europe covering all areas of astronomy. The census shows a high level of intent to implement the International Virtual Observatory Alliance (IVOA) protocols, and this is verified by the European entries in VO registries. VO usage is high as measured by service query statistics, although impact metrics are difficult to define when services are being accessed transparently via multiple tools and interfaces.

Members of the International Virtual Observatory Alliance. Image courtesy of IVOA

IVOA remains the international coordinating body for VO, and now comprises twenty-one organizations and VO initiatives. IVOA has matured as an alliance with established procedures for setting scientific and technical priorities for development of standards aligned with global member project priorities. Euro-VO continues to coordinate activities at the European level.

The Euro-VO AIDA project was completed successfully in 2010 and was followed by a bridging project EuroVO-ICE (2010-2011). The EuroVO-CoSADIE (2012-2014) project is currently defining the medium-term requirements to establish a sustainable European Virtual Observatory. The activities include support to science users and data centers, continued technological development of standards and tools, and forming an education network. CoSADIE supports the Euro-VO Science Advisory committee, which continues to play an important role with the capacity to define European science priorities that are transmitted to the international level through the IVOA Standing Committee on Science Priorities. Elements of the sustainability study include the need to maintain VO registry support, VO publishing tools, support to coordinated technological development, and support for professional engagement via schools and workshops.

The Virtual Observatory (VO) has been incredibly successful in integrating distributed infrastructures into one single virtual astronomy facility - the diversity of the various multi-messenger ESFRI facilities represents the obvious next step forwards. By ensuring that the ESFRI telescope products are openly accessible via the VO framework, the new-funded ASTERICS programme will facilitate the interoperability and re-use of these data, making them accessible to the full European and indeed international communities. This will support new and novel approaches to data exploitation, and provides a natural repository where reduced, open data products (e.g. survey legacy data) can be reliably maintained and curated. As in many other key areas, training and educating the next generation of facility staff and users will be essential.

Several constituents of the astronomy community are VO stakeholders:

- All astronomers are potential high-level users of the VO, and most already regularly benefit from it possibly without being aware of it, "hidden" in basic tools and services often taken for granted.
- The European VO School gathered interest from 10 EU countries, plus Serbia and Turkey.
- All data and service providers are also potential providers of VO-enabled data services. The wide interest of large agencies and projects as well as smaller infrastructures or research groups was demonstrated both during the European Data Centre Forum and during the IVOA Interoperability meeting, both organized by CoSADIE in 2013.
- Although the basic building blocks of VO infrastructure are available, it was also confirmed that continuous update of the framework of standards and tools is needed to be able to deal with new instruments and with intellectual developments in astronomy. Technical efforts are well focused thanks to the evolution of the IVOA which now sets priorities evaluated on scientific grounds.

2. MAIN ACTIONS TOWARDS A SUSTAINABLE VIRTUAL OBSERVATORY

The initial VO development phase has identified several strands of work needed to implement fully the Astronomical Virtual Observatory:

- Development of standards and protocols, and their international agreement;

- Construction of "glue" software components – portal, registry, workflow, user authentication, virtual storage
- Uptake by data centers, who need to "publish" in the system, i.e. to write VO compliant data services connected to their holdings;
- Construction of tools to take effective advantage of seamless access to data;
- Support to the scientific community in its uptake of the new framework.

All these strands of work remain relevant but their respective weights are evolving with time, as explained in the analysis performed at the end of the EuroVO-ICE project in August 2012. The most visible work of the VO during the early stages has been the development of the building blocks of the VO framework, interoperability standards and VO-enabled tools. In the operational phase, the focus is shifting towards maintenance and expansion of existing standards, support to take-up by data providers and astronomers, and outreach towards education. Experience has also shown that even as the VO matures, development of new standards does not cease because of scientific and technological evolution. Another important evolution, which has been conspicuous since the beginning, is linked to interdisciplinary aspects, both with nearby disciplines and at the level of general interoperability.

The CoSADIE project has recently identified the main activities required in a sustainable Virtual Observatory.

1) **Astronomical community support**: The EuroVO-AIDA project demonstrated that the most efficient way of promoting VO dissemination within the scientific community is through Hands-On workshops. This continues to be effective ways to disseminate knowledge on how to use the VO. Tutorials have to be regularly revised to keep abreast of the evolution of VO data and tools. The European schools allow reaching scientists from all EC countries, including those without national VO expertise, and further serve as templates for national events in more expert VO countries. Another way to reach scientists from countries with little or no national VO expertise is to organise "regional schools" to cover a specific country or larger region of the EC. This requires both local support and participation of Euro-VO staff.
2) **Data provider support**: Three tutorials on "How to publish data in the VO" were organized in 2007, 2008 and 2009, based on end-to-end usage of VO publication tools, the final one marking the end of a cycle in this activity. One aim goal of CoSADIE was to assess this question again by convening a Data Centre Forum to discuss the evolving needs of data providers. The Data Centre Forum assembled an enthusiastic audience of data providers strongly committed to share expertise and explore VO topics. Regular meetings are mandatory, including networking sessions to learn from one other and tutorials on specialized aspects of VO publishing rather than end-to-end procedures. Those from countries with experienced VO teams also stressed that for many of them the practical help of these teams has been a significant support for them to join the VO. Support to the VO take-up of data providers has several aspects: regular update of publication tools and of tutorials, regular data center forums including both networking and hands-on sessions, experienced VO teams able to do counselling to their national communities but also to data providers from other European countries.
3) **VO team support**: European VO expertise is concentrated in 5 countries: France, Germany, Italy, Spain and United Kingdom, and at ESA, the European Space Agency. ESO, the European Southern Observatory, an active participant in early development of the VO, has now become more a user. As explained above, there is a continuous need for maintenance of the VO framework, and these teams need support, though probably at a level less intense than in the past. Support is of paramount importance in several activities: development of VO standards and tools; participation in IVOA activities; development of

VO publication tools; R&D to assess the relevance of new technologies in the VO context; coordination of European technological activities; VO deployment by data providers throughout Europe; and sharing of expertise through hands-on schools and tutorials. VO teams are also a cornerstone of the support to take up by the science community. Core service activities include the maintenance, operation and curation of the Euro-VO Registry of Resources and of the Euro-VO web portal.

The identification and description of the activities required in a sustainable VO highlights the mature nature of the system in that these activities are well defined, and can be categorized and mapped to the roles of the different stakeholders. The sustainability assessments of these activities taken as a whole outline the technical readiness of Euro-VO as the VO moves into a fully operational phase.

3. CONCLUSION

CoSADIE has recently issued a 'Technical Sustainability Report' that addresses the main aspects that will be addressed in the future organization. First of all they have detailed the activities required in a sustainable VO, as presented in Section 2. Their analysis of the VO sustainability pointed out the questions related to the sustainability of the technical framework, of the IVOA and of the Euro-VO. Moreover they have provided a first estimation of the resources required for a sustainable Euro-VO. Their conclusions are summarized in their table 6.1:

ACTIVITY	Current	Required
Core Service Support	2.15	~ 6
VO Infrastructure Support	7.93	~ 11
VO Publishing Support	3.8	~ 8
Astronomy Community Support	7.07	~ 10
TOTALS	20.95	~ 35

CoSADIE Technical Sustainability Report
Current and required estimates of European VO Effort (FTE)

Their report has identified and described all of the elements which need to be in place to reach technical sustainability for the VO in Europe. The different aspects of Euro-VO are characterized as elements of technical sustainability from the viewpoint of the Data Providers, VO Teams and Astronomers. The activities required in a sustainable VO have been identified and classified into four main categories of Core Service Support, VO Infrastructure Support, VO Publishing Support and Astronomy Community Support. ASTRONET considers now that everything is in place to prepare a proposition of European Coordination for the VO. We consider as important to include this activity into the framework of the future Astronomy Coordination in Europe and we do not propose for the time being an independent Memorandum of Understanding.