

**Response to Call for White Papers for Universe Roadmap**  
*The National Virtual Observatory*

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*Science Goals of Mission or Technology Development*

If the past twenty-five years are any guide, the next quarter century will see technical advances and innovations that can barely be conceived today. The current revolution in information technology and data proliferation will continue. The dependence upon very high speed data access, comprehensive and rapid data assimilation and analysis, and growing cross-disciplinary interactions will continue to become ever more deeply imbedded into the fabric of society and into the framework for both ground- and space-based astronomical research. Internet-in-space initiatives, now just emerging, will form the basis for a new, highly integrated approach to mission operations, data processing, and data dissemination.

The Virtual Observatory (VO) concept—realized in the United States as the US National Virtual Observatory (NVO)—is at the forefront in exploiting this revolution in information technology and data access. Building on the strengths and vision of NASA's existing astronomy data centers, the NVO is now completing its initial development efforts and the foundations are being laid for a distributed NVO Facility. In twenty-five years the NVO will have become so deeply ingrained into the US astronomy research culture that it will have become a universal and indispensable aspect of astronomical research. Its presence will be taken for granted and its reliability and scope will be assumed, as will its continual utilization of current and emerging technologies. In the year 2030, virtually all astronomy data will be unified into a worldwide structure that will include rapid data mining, data discovery, and data federation. High speed and sophisticated data analysis tools will permit examination of any amount of data from any astronomical source, together with rapid and detailed comparisons between very large datasets and state-of-the-art theoretical models and simulations. VO datasets and tools will be intimately coupled with journal publications, allowing access to relevant data and model results from the journal articles themselves. New instrumentation initiatives will be designed from the start to be compatible with and take full advantage of VO standards and protocols, and the data from these new facilities will flow into VO-aware archives quickly and efficiently.

In addition to the more traditional astronomical data sets and theory models, the NVO and its accompanying technological advances will nurture an explosive growth in cross disciplinary endeavors. It is easy to see that datasets and theoretical models from the fields of planetary atmospheres, astrobiology, astrogeology, and seismology will merge in a natural way with existing astronomy databases and infrastructure. Additional contributions from climatology, biophysics, particle physics, and condensed matter physics can be envisioned, placing astrophysics at the nexus of a truly comprehensive approach to the study of the Universe from the Planck time to the formation and evolution of stars, planetary systems, and planetary interiors and

ecologies. This remarkable multidisciplinary synthesis can only result in accelerating our progress in understanding both the traditional “Universe” and its constituent components, from primordial energy fields to the emergence of life.

Finally, an essential role of VO projects, and NVO in particular, will be a growing presence in the educational process. All levels of society will have access to the VO, and by 2030 it will have become as much a part of the educational infrastructure as it will have the astronomy infrastructure. VO materials will be used to assist instruction in basic science, logic, experimental design, and statistics as well as the more traditional fields of physics, chemistry, and astronomy. This educational asset of the VO will be available at all levels of education, from pre-school to undergraduate and graduate studies. In addition to formal educational activities, the VO will have a large impact on the understanding of science by society as a whole. The ready availability of VO data and models, together with the enduring interest generated by astronomical topics and images, will ensure that a larger cross section of society will have a greater understanding of the Universe than ever before.

### *Description of Mission*

The NVO is not a mission in the traditional NASA sense. However, its goals of federating distributed datasets, enabling complex multi-wavelength data comparisons and analyses, supporting sophisticated data mining and pattern recognition applications, performing large-scale computations on remote/distributed data, and confronting observational data with theoretical simulations have tangible and measurable benefits for traditional missions. The ongoing NVO mission is to support these capabilities with increasing efficiency and flexibility through adoption of new IT technologies, and to provide a software and user support environment that brings VO tools and VO-enabled research to the astronomy community. VO tools and standards will simplify future software design, make implementation more efficient, and allow for greater re-use and adaptation of existing software. Astronomers will make optimal use of new NASA missions via the NVO, planning science programs, performing complex multi-disciplinary analyses, and reaching a more rapid understanding of new data in the context of existing knowledge.

### *Description of Required Technology Development Program*

To a large extent VO development rides the wave of advances in information technology. Advances in data management, databases, networks, process control, and workflows complement advances in hardware (large format detectors, higher processor speeds, increased memory and data storage). VO technologies are drawn from the IT universe, and are adapted and specialized for astronomical applications based on science goals and requirements. Through national and international collaboration, agreements are reached on standard interfaces and communication protocols that enable worldwide discovery and access to astronomical databases, archives, and computational services. VO technology development primarily relies upon maintaining currency with IT developments, building systems with interfaces that minimize direct reliance on any one technology, coordinating technology adoption with national partners, and vetting standards through national and international organizations (AAS, International VO Alliance, IAU).