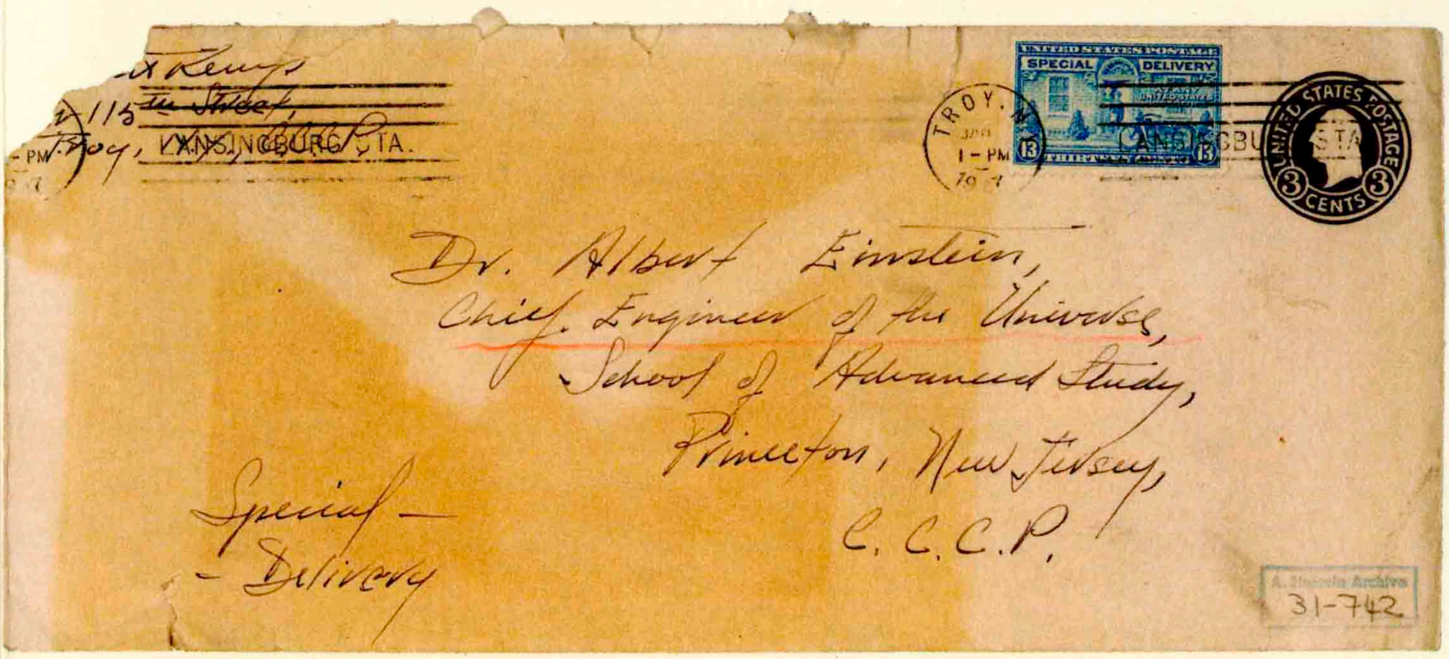

MAX-PLANCK-INSTITUT FÜR WISSENSCHAFTSGESCHICHTE

Max Planck Institute for the History of Science

RESEARCH REPORT 2004—2005

MAX-PLANCK-GESELLSCHAFT

Titel:
Envelope, addressed to Albert Einstein
„Chief Engineer of the Universe".
The Hebrew University, Jewish National &
University Library, Albert Einstein Archives,
Jerusalem, Israel, E. A. 031–742

Rückseite:
The entrance of the Institute's new building.
Architects: Dietrich Dietrich, Stuttgart

Most of the portrait photographs were done
by Skúli Sigurdsson, Berlin/Reykjavík

MAX-PLANCK-INSTITUT FÜR WISSENSCHAFTSGESCHICHTE

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Introduction

Modern societies are saturated with science and technology. Spatial patterns—whether high-rise clusters or low-rise sprawls—and temporal rhythms, ever accelerating, reveal how profoundly science and technology have influenced the very framework of modernity. These influences penetrate deep into the realm of meaning as well as that of matter. The prestissimo pace of scientific innovation challenges citizens and leaders of modern polities to reform, create, or scrap values and institutions in order to integrate (or reject) the new possibilities. The understanding of what counts as knowledge, of truth itself, has been shaped not only by the results, but also by the historical development of the sciences.

The Max Planck Institute for the History of Science (MPIWG) studies this development in breadth and depth. Its research projects span ancient Babylonian mathematics and the human genome project, the rise of the twentieth-century neurosciences and the decline of Renaissance chronologies. Many projects are comparative, both historically and cross-culturally: for example, *longue durée* studies of mechanics from classical Greek and Roman antiquity to quantum mechanics, embracing not only learned treatises but also the practical knowledge crystallized in Italian fortifications and traditional Chinese market balances. The sources consulted for these projects include not only texts and images, but also objects; the forms of publication have expanded from books and articles to embrace websites like the Virtual Laboratory, films like "Visualizing Science at Work: C.T.R. Wilson's Cloud Chamber Experiment", and museum exhibitions like "Einstein: Chief Engineer of the Universe" as well.

The common thread running through these diverse projects is a thoroughgoing awareness of the historicity of science, the concomitant of the restless process of innovation. The historical character of science (understood in its widest and least anachronistic sense as any body of systematic knowledge) emerges at multiple levels: most obviously at the level of empirical findings and changing theories, but also at the level of which objects are selected for scientific inquiry and how they are investigated and explained. That is, the ontology and the epistemology of the sciences change over time, often dramatically. New forms of inquiry, such as experiment and observation, categories of explanation, such as cause and correlation, and epistemic virtues, such as objectivity and certainty, are invented and refined. So are new objects, such as the chemical element and the gene, and new personae, such as the naturalist and the experimenter.

All of these novelties appear in a specific historical context, a particular time and place, and often build upon local resources of knowledge and skill: for example, early modern chemists drew upon the classifications of materials devised by apothecaries, metal workers, and other craftsmen. Yet scientific and technological innovations also spread: local knowledge becomes universal knowledge. Both moments of scientific change, emergence and diffusion, are fundamental to the research conducted at the MPIWG.

Because current scientific disciplines are themselves products of these historical processes, most research at the MPIWG is not organized along disciplinary lines. Although several research projects are concerned with changing classifications of knowledge, contemporary divisions like those between the natural and human sciences, or between the laboratory and field sciences, are more likely to be the objects rather than the presuppositions of historical investigation. Instead, research is generally structured by over-arching categories like “deduction” or “experiment”, rather than the “history of physics” or the “history of biology”. Moreover, knowledge is understood ecumenically, to embrace, for example, the know-how of engineers as well as the demonstrations of mathematicians. Depending on period and problem, the relevant historical context expands and contracts.

Research is the core activity of the MPIWG. But 2004—5 have been eventful years for Institute in other respects as well. In 2005 scholars in Department I made signal contributions to the events of the Einstein Year, especially the remarkable exhibition that officially opened on May 12 in Berlin. Also in 2005, the Institute’s new building in Dahlem (see back cover), designed by the Stuttgart architects Dietrich + Dietrich, was completed (we moved in February 2006). A proposal for a five-year Max Planck Society Research Network on “The History of Scientific Objects” was approved; the organizational meeting of the international network of cooperating institutions (from Germany, France, Italy, the United Kingdom, and the U.S.A.) took place at the MPIWG in September 2005. With the help of the Max Planck Society and the MPIWG Board of Trustees, negotiations were begun with the Freie Universität Berlin and the Humboldt-Universität zu Berlin to create new professorships and independent junior research groups in the history of science, thereby formalizing and strengthening the MPIWG’s links with neighboring universities.

In 2004, the MPIWG celebrated its tenth anniversary, but amidst all the happy changes of the past two years covered by this report, we feel that we have been given the opportunity to begin afresh. This would not have been possible without the wise counsel of our Scientific Advisory Board, the generous support of the Max Planck Society and other funding organizations, the good cheer and efficiency of our staff, and, above all, the intellectual stimulation of the scholars young and old, from near and far, who keep the Institute buzzing. We thank all most heartily.

Lorraine Daston
July 2006

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Prof. Dr.
Jürgen Renn

DIRECTOR *Prof. Dr. Jürgen Renn*

RESEARCH SCHOLARS *Dr. Peter Beurton, Dr. Katja Bödeker, Dr. des. Ing. Claudia Bührig* (until May 2005), *Jochen Büttner, Giuseppe Castagnetti, PD Dr. Peter Damerow, Brian Fuchs, Prof. Dr. Dieter Hoffmann, Dr. Malcolm Hyman, Dr. Horst Kant, Dietmar Kurapkat, Prof. Dr. Wolfgang Lefèvre, Dr. Christoph Lehner, Dr. Jürgen Neffe* (until June 2004), *Dr. Albert Presas i Puig, Simone Rieger, Matthias Schemmel, Markus Schnöpf* (until February 2005), *Dr. Volkmar Schüller, Matteo Valleriani, Milena Wazeck*

Department II: Ideals and Practices of Rationality

Prof. Dr.
Lorraine Daston

DIRECTOR *Prof. Dr. Lorraine Daston*

RESEARCH SCHOLARS *Dr. Mechthid Fend, Dr. Anke te Heesen, Dr. Bernhard Kleeberg, Dr. Christine von Oertzen, PD Dr. Fernando Vidal, Dr. Annette Vogt, Dr. Kelley E. Wilder*

Department III: Experimental Systems and Spaces of Knowledge

Prof. Dr. Hans-
Jörg Rheinberger

DIRECTOR *Prof. Dr. Hans-Jörg Rheinberger*

RESEARCH SCHOLARS *Dr. Christina Brandt* (since February 2006: Senior Research Scientist), *PD Dr. Sven Dierig, Dr. Uljana Feest, Dr. Peter Geimer* (until March 2004), *PD Dr. Christoph Hoffmann, Dr. Julia Kursell, Dr. Staffan Müller-Wille* (until September 2004), *Dr. Henning Schmidgen, Prof. Dr. Friedrich Steinle* (until August 2004)

Independent Research Group I (January 1999–December 2004): History and Philosophy of Laboratory Sciences

DIRECTOR *PD Dr. Ursula Klein*

PD Dr.
Ursula Klein

Independent Research Group II (April 1999–February 2007): Experimental History of Science

DIRECTOR *PD Dr. H. Otto Sibum*

RESEARCH SCHOLAR *Annik Pietsch*

PD Dr.
H. Otto Sibum

Service Units

Administration headed by *Claudia Paaß*

Library headed by *Urs Schoepflin*

Information Technology headed by *Dirk Wintergrün*

Research Coordination *Jochen Schneider*

Claudia Paaß

Urs Schoepflin

Dirk Wintergrün

Jochen Schneider

The new Independent Research Group "From Invention to Innovation. Cultural Traditions of Technical Development in China," headed bei PD Dr. Dagmar Schäfer, will start its work by October 2006.

From left to right, back rows:
Paul Trzeciok, Anna Holterhof,
Peter Damerow, Lindy Divarci,
Matteo Valleriani, Sadiye Leather-Barrow.

Middle row:
Massimiliano Badino, Daniela Monaldi,
Dietmar Kurapkat, Miriam Gabriel,
Brian Fuchs, Simone Rieger,
Peter McLaughlin, Carmen Hammer,
Dieter Hoffmann, Giuseppe Castagnetti.

Front row:
Jürgen Renn, Malcolm Hyman,
Ulrike Fauerbach, Christoph Lehner,
Wilhelm Osthues.

Department I

Structural Changes in Systems of Knowledge

Director: *Jürgen Renn*

The work of the research group headed by Jürgen Renn is mainly dedicated to understanding the historical processes of structural changes in systems of knowledge. This goal comprises the reconstruction of central cognitive structures of scientific thinking, the study of the dependence of these structures on their experiential basis and on their cultural conditions, and the study of the interaction between individual thinking and institutionalized systems of knowledge. This theoretical program of an historical epistemology is the common core of the different investigations and research projects pursued and planned by the research group.

In order to cover at least some of the major developmental steps in the history of science, research is pursued in four different areas: the emergence of formal sciences such as mathematics; the emergence of empirical sciences such as physics, chemistry, and biology; structural changes in sciences with developed disciplinary structures and integrated theoretical foundations, such as the transition from classical to modern physics; and the role of reflective thinking and second-order concepts in science.

Present research in these areas focuses on four central projects:

1. the relation of practical experience and conceptual structures in the emergence of science,
2. reorganizing knowledge in developed science,
3. the long-term history of the unwritten knowledge that has made the great architectural achievements of mankind possible, and
4. transfer and transformation processes of knowledge across different cultures.

The first project seeks to understand the emergence of fundamental concepts of empirical science arising from the reflection of practical experiences, prior to the period in which experiments became the dominating experiential basis of science.

The second project studies processes of knowledge organization, focusing on the rise and decline of the mechanical worldview.

The third project deals with an epistemic history of architecture and analyzes the knowledge implicit in actions that emerged long before the advent of science, and that was repeatedly subjected to transformations that explain the fascinating interplay of utility, rationality, and art that is the hallmark of architecture.

Dancing with Gravity. L. Taudin

The fourth project, which has just been awarded a major grant by the Strategic Innovation Fund of the Max Planck Society (MPG), focuses on the conditions, pathways, and consequences of globalization processes of knowledge, relating them to present processes of globalization, in particular those involving the development of the Internet and the global organization of science.

Two further areas of work belong to what may be called "history of science in action." One of these areas of activities is dedicated to developing advanced tools for an historical epistemology. In this area, new electronic media are used and developed—in close co-operation with the IT-group of the Institute—to explore innovative ways of creating access to the empirical basis of the history of science. Central to the second area was a major effort to realize new forms of combining scholarly communication with a public outreach of the history of science, mainly in the context of the exhibition "Albert Einstein: Chief Engineer of the Universe."

During the period covered by this research report, several goals of these projects have been reached and new targets have been set. In the context of the first project, focusing on the development of mechanical knowledge, the acquisition, analysis, and commentary of a substantial part of the relevant primary sources has been accomplished and significant dissertation projects have been completed. The joint work with the Partner Group at the Institute for the History of Natural Sciences of the Chinese Academy of Sciences in Beijing has yielded contributions to the reconstruction of the long-range development of mechanical thinking in China and to the understanding of the interaction between western scientific knowledge and that of the Chinese tradition.

As the research projects of the department have to integrate knowledge from a wide range of disciplines, cultures, and historical periods, they are realized in co-operative networks extending well beyond the boundaries of the Institute. The Institute typically represents, however, a central node of such networks, bringing together scholars to form teams characterized by intense co-operation over longer periods of times. The challenges of cross-cultural comparisons, diachronic studies of historical developments, and the close integration of computer-assisted source analysis and scholarly interpretations are addressed with the help of a combination of core teams, who bear the main responsibility for a project and an array of informal working groups which are often independently funded, characteristically shaped by the interests of younger scholars and connected by weaker or stronger links to the activities of the core team. Exploring and validating theoretical conclusions with reference to the vast collection of primary sources, but also building upon the existing scholarly literature would be inconceivable without the help and active participation of the Institute's library and information management facilities built up with the support of the IT-group.

It has been possible to substantially expand the ongoing investigations in the context of the first project by complementary projects funded by third-party resources. Since January 2005, the department participates in the DFG Collaborative Research Center (SFB) *Transformations of Antiquity*, which brings together ten humanities disciplines from the Humboldt University in Berlin, two subjects from the Freie Universität Berlin, and the Max Planck Institute for the History of Science (MPIWG) to collaborate in sixteen projects with around fifty academic researchers from six different faculties altogether. The SFB concentrates on the transformation processes by which European cultures, arts, and sciences have formed themselves in a continuation of the cultures of antiquity. The work of the department in the framework of the SFB focuses on the sub-project "Weight, Energy and Force: Conceptual Structural Changes in Ancient Knowledge as a Result of its Transmission" (Malcolm Hyman, Matteo Valleriani).

Worldviews at the Einstein Exhibition.

It has furthermore been possible to obtain a grant from the German-Israeli Foundation for Scientific Research and Development (G.I.F.) that partially funds a joint research project "Jesuits on Statics, Dynamics, Mathematics and Astronomy between Galileo and Newton." This project has been undertaken together with the Cohn Institute for History and Philosophy of Science and Ideas at Tel Aviv University to complement the study of an important aspect of the development of mechanical knowledge: the dissemination and transmission of scientific knowledge in the early modern period through the highly developed communicative network of Jesuit colleges and universities (Jochen Büttner, Peter Damerow, Rivka Feldhay).

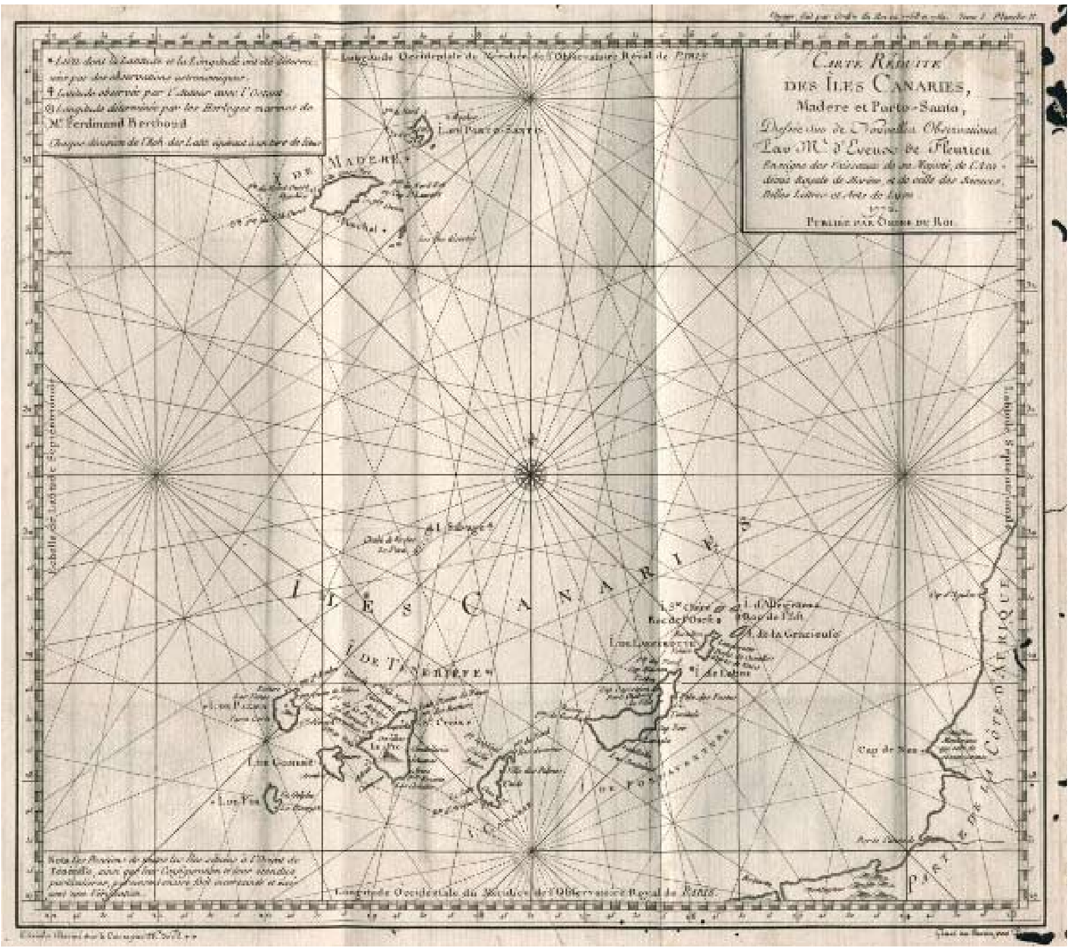
A central part of the second project, focusing on the relativity revolution, has been brought to a close. The four-volume series *The Genesis of General Relativity*, comprising over 2000 pages and presenting the comprehensive results of this part of the project, have been prepared for publication at the Institute and are now in press. Work on these volumes has been complemented by several other activities, including the Internet publication of key primary sources relevant to the relativity revolution, the organization of a major international conference on the history of general relativity, and work on a dissertation project on the opposition to the theory of relativity in the broader public in the 1920s.

Preparations to extend the reconstruction of the conceptual revolution of modern physics to the case of the quantum theory with the aim to similarly trace its roots in the developments of classical science have been further pursued. They have led to initial results, which are being prepared for publication, as well as to the formation of an extensive worldwide network of collaborations—involving both physicists and historians of science. In particular, a joint project proposal together with the Fritz Haber Institute of the MPG to the Strategic Innovation Fund of the President of the Society concerning the history of quantum mechanics has just been granted.

In the context of the third project, dedicated to the epistemic history of architecture, undertaken jointly with the Bibliotheca Hertziana (Max Planck Institute for the History of Art) in Rome and funded by a special grant from the MPG, a number of conferences and workshops have taken place and several publications prepared. In addition, an exhibition project on the Hagia Sophia has been realized and numerous primary sources relevant to the project published on the Internet. These achievements were possible despite the difficulties that arose when the project head from the MPIWG left the department to take up a permanent position.

Preparations for the fourth project, dealing with the globalization processes of knowledge, have just begun during the period of this research report. It aims at integrating

Voyage fait par ordre du roi en 1768 et 1769 à différentes parties du monde pour éprouver en mer les horloges marines ...
Ferdinand d'Eveux, 1773



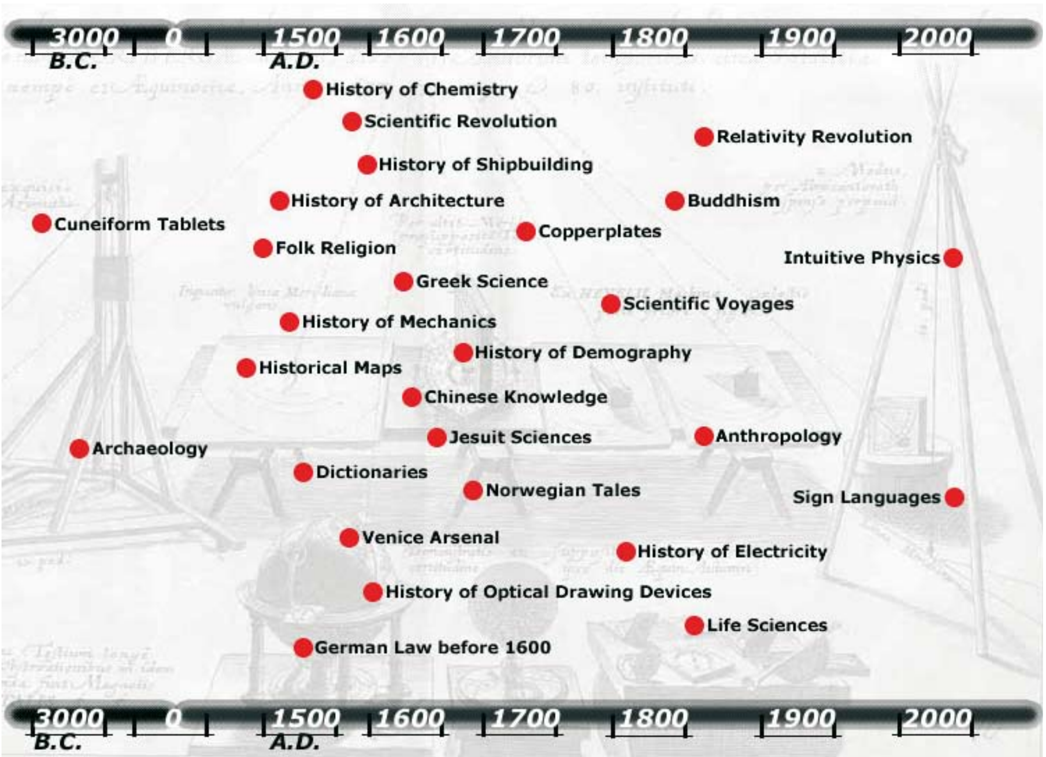
various activities under a common thematic umbrella that have so far been undertaken in isolation, or under a more technical perspective. Research on the invention of writing and the emergence of mathematical thinking in ancient Babylonia that has been pursued since the foundation of the Institute is now increasingly being brought into contact with the study of parallel processes in other cultures, such as China, India, and the New World. Research on European scientific expeditions that sailed to America, Africa, the Pacific and Indian Oceans, as has been undertaken in the context of the Humboldt project (a joint project with the Fundación Canaria Orotava de Historia de la Ciencia, funded by the Government of the Autonomous Region of the Canary Islands), is being redirected to analyze the conditions, structures, and consequences of transatlantic knowledge transfer in colonial and post-colonial times <http://humboldt.mpiwg-berlin.mpg.de/>.

All central research activities of the department draw heavily on the potential of the new media and hence require new forms of integrating scholarly with technical competence. The reliance on access to large corpora of sources also requires strategic alliances with holders of sources such as libraries and archives. The Cuneiform Digital Library Initiative (CDLI), a pioneering endeavor launched in 2000 by the Institute together with the University of California at Los Angeles, with support from the US National Science Foundation (NSF), has therefore not only introduced advanced techniques of electronic information management into scholarly work, but has also created an international network of research institutions, universities, and museums with the aim to virtually rejoin and analyze cuneiform archives now scattered in numerous museum collections (Jacob Dahl, Peter Damerow, Robert Englund) <http://cdli.ucla.edu>. In a similar way, the Archimedes Project (see below), originally funded by a major grant received from the NSF and the Deutsche Forschungsgemeinschaft, has enabled the historical reconstruction of mechanical knowledge—central to the first project—to be addressed in a much more systematic way than was previously possible. Such projects are part of a fundamental restructuring of scholarly work in the humanities and demand flexible structures of research, innovative institutional infrastructures, and also the support of creative science policies in overcoming the resistance of traditional working modes. In the period under consideration, these projects took a new direction. Whereas previously they had concentrated on acquiring data such as digital images and transcriptions and on developing tools for presentation and mark-up, they turned more and more from data-acquisition to content-curation and content-enrichment, and to the development and exploitation of language technology for semantic access and analysis.

The experiences of pioneering ventures such as the Archimedes Project <http://archimedes.mpiwg-berlin.mpg.de> and the CDLI project, undertaken in the context of the scholarly work of the department, have provided the background for the creation of novel support structures for research information management at various institutional levels. The European Cultural Heritage Online (ECHO) initiative (coordinated by Simone Rieger) was launched in 2002 in collaboration with sixteen European partners, including two other Max Planck Institutes (Max Planck Institute for Psycholinguistics in Nijmegen and the Bibliotheca Hertziana in Rome) and funded by the European Commission. Its aim is to create an open-access infrastructure bringing cultural heritage online. In the period under consideration, ECHO significantly extended, also with the help of a grant from the Government of the Autonomous Region of the Canary Islands, the spread, volume, and variety of sources of cultural heritage—well beyond the range of European culture—which it makes available under the open-access paradigm. It has meanwhile been developed to encompass over fifty scientific and cultural institutions and to present more than 130,000 high-resolution images and 54,000 full-text page transcriptions in several languages <http://www.echo-project.net>.

→ "The Virtual Laboratory" p. 100

ECHO has led to the creation of a generic and sustainable infrastructure, presented in 2004 at an international conference funded by the European Commission. It has also prepared a common ground for a great variety of IT-based projects within the MPG and beyond, offering an 'agora,' a forum of interchange between content providers, scholars, developers, and the public-at-large. The success of the ECHO initiative can be considered as a proof of principle of the 'agora dynamics' constituted by the cumulative enrichment of existing 'seed collections,' the interlinking of different corpora, and the generalization of specific instruments into modules of a generic infrastructure.



Seed Collections. Made publicly available within the ECHO infrastructure, http://www.echo-project.net

This success has become one of the points of departure for the creation of the Max Planck Digital Library (MPDL), conceived as a new central scientific service unit of the MPG responsible for strategic planning as well as the development and maintenance of electronic infrastructures that will provide the institutes with scientific information and support web-based scientific communication. It will integrate existing activities, among them a five-year project undertaken jointly by the MPG and the Fachinformationszentrum Karlsruhe (FIZ) and supported by the Federal Ministry for Education and Research (BMBF). This project starts from existing innovative paradigms, such as the ECHO platform, that will be evolved, in the context of this project, into a generic scholarly workbench representing an essential part of the future Max Planck digital infrastructure <http://www.escidoc-project.de>.

The success of innovative infrastructures for the humanities, such as the ECHO platform, has also triggered a Europe-wide effort to develop large-scale research infrastructures, for the humanities too, an effort that is reflected both in the foci of the Seventh Framework Program and the intergovernmental ESFRI process (European Strategy Forum for Research Infrastructures). The vision of the Internet as a medium offering open access to both science and culture is implicit in the ECHO Charter and was later formulated in the widely acclaimed Berlin Declaration <http://www.zim.mpg.de/openaccess-berlin/berlindeclaration.html>. The Berlin Declaration, meanwhile signed by more than 160 institutions worldwide, was launched by the MPG in 2003 at an international conference organized by the MPIWG and became a key issue at the first World Summit on the Information Society, held in Geneva in 2003. The Berlin Open Access Conference 2003 was the first in a series of international open-access conferences. These brought together the rapidly growing number of signatories of the Berlin Declaration in order to design a common roadmap, to discuss the creation of institutional repositories, as well as the conditions for open-access publications on the background of a historical change in the media of knowledge production and dissemination.

The potential of the history of science as a mediator between science and society has been explored in yet another dimension during the period covered by this report, by exploring new forms of combining scholarly communication with public outreach. The external occasion for this exploration was provided by the International Year of Physics and the celebration of the Einstein Year 2005 in Germany. The Institute's central role in shaping this year also created numerous occasions for young historians of science to explore a wide-range of professional options, ranging from exhibition making, via didactics in the history of science for all age levels, to science journalism. The key event of this year was the large exhibition "Albert Einstein: Chief Engineer of the Universe" of the MPG, held from May to September 2005 at the Kronprinzenpalais, Unter den Linden in Berlin, conceived by the Institute, and funded by the MPG along with numerous other sponsors. The exhibition and its comprehensive accompanying program realized new ways of presenting the results of historical investigations of science in its cultural, technological, and political contexts to a broader public <http://www.einsteinausstellung.de>.

The research, development, and outreach activities in the period covered by this report have created the conditions for a significant extension of the network of scholarly cooperations beyond the department's traditional partners in Europe and the US. The ECHO initiative, the activities during the Einstein Year, and the preparation of the new globalization project have stimulated institutions throughout the world to seek scientific cooperation and participation in the department's projects and initiatives. With regard to Africa, the ECHO infrastructure has become an instrument for overcoming the digital divide, creating access to cultural heritage from Sudan and Mali (Cornelia Kleinitz) <http://echo.mpiwg-berlin.mpg.de/content/ethnologycollection/dogon>. With regard to Asia, the department's cooperation with the Partner Group at the Chinese Academy of Sciences has been strengthened by the perspective of establishing a new Junior Research Group at the Institute to investigate innovation processes and traditions of technical development in China. Furthermore, the potential for scientific collaboration between academic and cultural institutions in Mongolia and the MPG was explored in 2005 by a visit from a MPG delegation, including members of the department, that resulted in the prospect of an extension of both the ECHO network and the scope of the globalization project. Similar cooperations are under negotiation with academic institutions in Uzbekistan. With regard to Latin America, the existing cooperation with Brazilian institutions has been consolidated while new cooperations with scholars and institutions in Cuba and Mexico have been launched.

Project 1

The Relation of Practical Experience and Conceptual Structures in the Emergence of Science: Mental Models in the History of Mechanics

General Goals of the Project

The goal of the project is to study the causes and long-term developments of scientific knowledge. The project is focused on mechanics as a part of science that has extraordinary significance for the development of science in general. In particular, and more so than other disciplines, mechanics has a continuous tradition from its origins in antiquity to the elimination of fundamental categories of mechanics by modern physics. Presently, the scope of the project is restricted to the period from antiquity to the emergence of classical mechanics in early modern times. However, it is intended to follow up the research questions of the project to the twentieth century.

The peculiar longevity of mechanics has given rise to speculations that the experiential basis of such scientific knowledge must be of a special kind, distinct from that of other sciences, which emerged much later. It has been claimed, for instance, that knowledge in mechanics or in mathematics is rooted in an essentially universal everyday experience, or even based on *a priori* structures of thinking. However, these and other speculations involve a very restrictive notion of experience. They exclude the by no means universal experience that human beings acquire in a historically specific material environment when dealing, for example, with the technology of their times. Therefore, the project is focused in particular on the historical reconstruction of such collective, practical experiences and their influences on the structure and content of scientific knowledge. Its main goal is to study the role of practical experience for the emergence and development of fundamental scientific concepts of mechanics, such as those of space, matter, force, time, and motion, and to reconstruct the patterns of explanation they were used for.

➜ "Experimental History of Science" p. 143
➜ "Materials in the History of Science and Technology" p. 127

An analysis of the relation between the various layers of knowledge and their development requires an appropriate description of their architecture. Evidently, formal logic is of little help here. In contrast to the inferences of formal logic, scientific conclusions can be corrected. Not only scientific knowledge but in fact large domains of human experience are not simply lost when theories are revised, even if this knowledge does not explicitly appear in such theories. In our description of the architecture of scientific knowledge we therefore make use of concepts from default logic such as the concept of a mental model, adapting them to an account of the historical development of the shared knowledge at the basis of science. We conceive of mental models as knowledge representation structures based on default logic which allow inferences to be drawn from prior experiences about complex objects and processes even when only incomplete information on them is available. Mental models relevant to the history of mechanics either belong to generally shared knowledge or to the shared knowledge of specific groups. Accordingly, they can be related either to intuitive, to practical, or to theoretical knowledge. They are, in any case, characterized by a remarkable longevity—even across historical breaks—as becomes clear when considering examples such as the mental models of an atom, of a balance, of the center of gravity, or of positional weight. Their persistence in shaping the shared knowledge documented by the historical sources becomes particularly apparent in the consistency of the terminology used, a consistency that offers one important element for an empirical control for the reconstruction of such mental models and their historical development.

Some of the overarching questions of this project are also pursued in the framework of the European Science Foundation (ESF) Research Networking Programme "From Natural Philosophy to Science," co-initiated by the department in 2002 <http://www.esf.org/esf_article.php?language=0&article=334&domain=4&activity=1>; <http://www.phil.kun.nl/center/esf/>. The program focuses on the factors involved in transforming natural philosophy into the physical sciences. The period covered extends roughly from the introduction of Aristotle's works into the nascent universities to the establishment of stable scientific institutions such as the Royal Society or the Académie des Sciences, whose activities were characterized by experimentation, mathematical modelling, the publication of research results (in vernacular scientific languages), and the sponsoring of scientific collaboration. The program is subdivided into four teams, each of which organizes four workshops in the period 2003–2007. One of the workshops, to which the department contributed, entitled "Mechanics and Natural Philosophy: Accommodation and Conflict," was held in Tenerife in 2004 and was devoted to key factors shaping the "mechanization of the world picture." Another workshop "The Machine as Model and Metaphor" will be held in Berlin in 2006.

Intuitive Mechanics

Mechanical knowledge significantly predates any systematic theoretical treatment of mechanics. The most basic knowledge presupposed by mechanics is based on experiences acquired almost universally in any culture by human activities. It includes the perception of material bodies and their relative permanence, their impenetrability, their mechanical qualities, and their physical behavior. The outcome is an "intuitive mechanical knowledge" embedded in a qualitative physics, which is built up in ontogenesis and guides human activities related to our physical environment <http://echo.mpiwg-berlin.mpg.de/content/intuitivephysics>.

A dissertation project on intuitive physics (Katja Bödeker) has been completed. In view of the lack of sufficient empirical evidence on the universal character of intuitive physics, the project has included field research both in Germany and on the Trobriand Islands. The first step was a study with German school children, conducted with the aim of analyzing the ontogenetic development of intuitive conceptions of force, motion, weight, and density. In order to examine which aspects of intuitive physical thinking and its development belong to universal cognitive structures, a parallel investigation was carried out in Kiriwina (Trobriand Islands, Papua New Guinea). The same tasks given to the German school children were presented to Trobriand children and adults. To control for possible influences of schooling, two groups were studied: the first group consisting of children attending the Catholic mission school in Gusaweta, and the second group consisting of illiterate adults and children living in a remote Trobriand village (Iuwada). The evaluation of the extensive documentary material collected during the expedition has been completed.

Children experimenting with a vacuum in the Comenius-Garden in Berlin.

Professional Knowledge of Practitioners

A second kind of mechanical knowledge, which predates any systematic theoretical treatment of mechanics, is the knowledge achieved by the use of mechanical tools. In contrast to intuitive mechanical knowledge, this type of knowledge is closely linked to the production and use of tools by professionalized groups of people and it consequently develops in history. The professional knowledge of practitioners is historically transmitted by immediate participation in practices such as the processes of labor and production in which such tools are applied and by the oral explanation that accompanies their application. Research on professional knowledge related to mechanics has been mainly dedicated to the study of the tradition of engineering knowledge in the early modern period. To facilitate the study of contemporary engineering drawings and to enable systematic comparisons of the wealth of information contained in these drawings, an analytical database has been developed that allows a standardized description of the images and enables systematized comparisons, as is customary for texts or quantitative data (Wolfgang Lefèvre, Marcus Popplow). This database meanwhile comprises around 1,500 engineering drawings ranging from the late middle ages until 1650 and includes hitherto unpublished materials. It will be published as an open-access resource in the framework of the ECHO initiative. A volume on the use, function, and consequences that engineering and architectural drawings had for Renaissance engineering has been published (Wolfgang Lefèvre).
In the early modern period, the increased significance and advancement of technology confronted the traditional body of mechanical knowledge with "challenging objects," such as the trajectory of projectiles, the stability of constructions, the oscillation of a swinging body, or the curve of a hanging chain. As becomes clear from the outstanding example of Galileo's *Two New Sciences*, these objects enriched the traditional

knowledge but also induced fundamental revisions of its structure, which led eventually to classical mechanics. A dissertation project dedicated to Galileo's activities as an engineer-scientist (Matteo Valleriani) has investigated conditions of this change and also sheds new light on hitherto neglected contexts of his writings. Complementing earlier findings about the relation between Galileo's science and practical knowledge with regard to his theory of motion and to his theory of the strength of materials, it has turned out that Galileo's conception of heat as exposed in his *Il saggiatore* in 1623 is rooted in the practical knowledge of contemporary engineers too, in this case in the knowledge of those who worked on pneumatics. In addition, research on the professional knowledge employed in shipbuilding has been continued, extending earlier research on knowledge organization in the Venetian Arsenal (Matteo Valleriani) and also on the relation between ship design and developments in fluid mechanics (Horst Nowacki).

Origins and Expansion of Theoretical Mechanics

Sources documenting early forms of mechanical knowledge and in particular ancient Greek and Latin texts on mechanics are being analyzed in order to reconstruct the emergence and developments of the first scientific representations of mechanical knowledge and the relation to intuitive knowledge and the professional mechanical knowledge of practitioners. Similarly, source texts from the early modern period, which is characterized by a rapid advancement of mechanical knowledge, are being investigated with the aim of understanding the transformation of ancient bodies of knowledge under the conditions of a different material and social culture. These investigations are also being pursued in the context of the SFB "Transformations of Antiquity" and the G.I.F. project "Jesuits on Statics, Dynamics, Mathematics and Astronomy between Galileo and Newton" <http://echo.mpiwg-berlin.mpg.de/content/jesuit>.

➔ "Knowledge and Belief" p. 61

In conjunction with the Archimedes Project (Brian Fuchs, Peter Damerow, Mauricio Gatto, Peter McLaughlin, Jürgen Renn, Urs Schoepflin), a collection of several hundred sources related to mechanics has been accessioned and prepared for inclusion within the digital library. Whereas previously the Archimedes Project had concentrated on acquiring data such as digital images and transcriptions and on developing tools for presentation, in the period covered by this report, the project focused on content-curation and content-enrichment. Particular emphasis was placed on the development of workflows and tools for text correction, the generation of parallel texts in different languages, and dictionary supplementation. Parallel texts (Greek/Latin, Latin/Italian, and Greek/Latin/Italian, also English when available) were produced for central texts in the history of mechanics by authors such as Guidobaldo del Monte, Jordanus, Lucretius, and Heron of Alexandria. The project has developed a workflow for capturing new word formations and adding them to the project's online tools, such as the morphological analyzer and the search facilities, in order to make unusual linguistic structures, such as the increasing occurrence of Latin neologisms in early modern texts amenable to analysis <http://archimedes.mpiwg-berlin.mpg.de>.

The analysis of such a huge body of texts with new, computer-assisted methods has yielded new insights into the shared knowledge structures that shaped mechanical thinking and the long-term development of these structures. The force of the shared knowledge resources of early modern mechanics, in addition to common challenges and the similar social environment of patronage conditioning the communication of scientific information, on the work of contrasting authors such as Galileo, Harriot, Stevin, or Descartes has been a main focus of research in the period covered by this report, in particular in the context of two dissertation projects.

In sequel to the extensive work invested into making Galileo's manuscripts accessible on the Internet, his notes on mechanics are being analyzed in the context of a dissertation project (Jochen Büttner). A detailed reexamination of this vast collection of research notes reveals, contrary to the published *Discorsi*, the challenging problems that motivated and shaped Galileo's thinking. It turned out that the problem of reducing the properties of pendulum motion to the laws governing naturally accelerated motion on inclined planes was the mainspring for the formation of Galileo's comprehensive theory of naturally accelerated motion. It could furthermore be shown how explorative experimentation substantiated the conceptual structures of the emerging theory. The dissertation was deliberately written in a format suitable for both print and electronic publication and thus for a seamless integration into the existing electronic representation of Galileo's notes on motion via hyperlinks.

Another dissertation project that was dedicated to similar research notes by Thomas Harriot, one of Galileo's most important contemporaries, has been completed and is being prepared for publication (Matthias Schemmel). Harriot and Galileo exploited the same shared knowledge resources in order to approach the same challenging subjects. While the paths Harriot traces through the shared knowledge are different from Galileo's, the work of the two scientists displays striking similarities as regards their achievements as well as the problems they were unable to solve. The study of Harriot's parallel work thus allows the exploration of the structure of the shared knowledge of early modern mechanics, to perceive possible alternative histories, and thus to distinguish between individual peculiarities and shared structures of early modern mechanical reasoning.

Independent Tradition and Knowledge Transfer—the Case of China

The question of whether science originated only once in history or whether it has multiple origins has rarely been analyzed as systematically as, for example, the structurally similar question of the single or multiple origin of the human species. The default assumption is still that science represents a human enterprise that, while having received contributions over time from various cultures, has actually originated only once, in Greek antiquity. The research activity on the science of mechanics in China has shed new light on the question of independent developments of knowledge, challenging the rationale behind default responses (this line of research will in the future be supplemented by the work of the Independent Research Group "From Invention to Innovation: Cultural Traditions of Technical Development in China"). It has also helped to understand the transformation processes of scientific knowledge when transferred from its culture of origin to another.

In joint work with the Partner Group at the Institute for the History of Natural Sciences of the Chinese Academy of Sciences, the exchange of practical and scientific knowledge between China and Europe in the early modern period has been investigated (Chen Yue, Peter Damerow, Jürgen Renn, Matthias Schemmel, Tian Miao, Xiao Yunhong, Yin Xiaodong, Zhang Baichun, Zou Dahai). In the period covered by this report, several working meetings have taken place, involving the members of the Partner Group's advisory board as well as further collaborators of the Institute (in addition to the names already mentioned, William Boltz, Rivka Feldhay, Fung Kam-Wing, Malcolm Hyman, Liu Dun, Simone Rieger, Urs Schoepflin, Hans Ulrich Vogel).

Workshop with the research group of Dept. I, the Chinese Partner Group and the Advisory Board. Beijing, 2004. From left, Rifka Feldhay, Tian Miao, Fung Kam-Wing, Jürgen Renn, Simone Rieger, Matthias Schemmel, Hans-Ulrich Vogel.

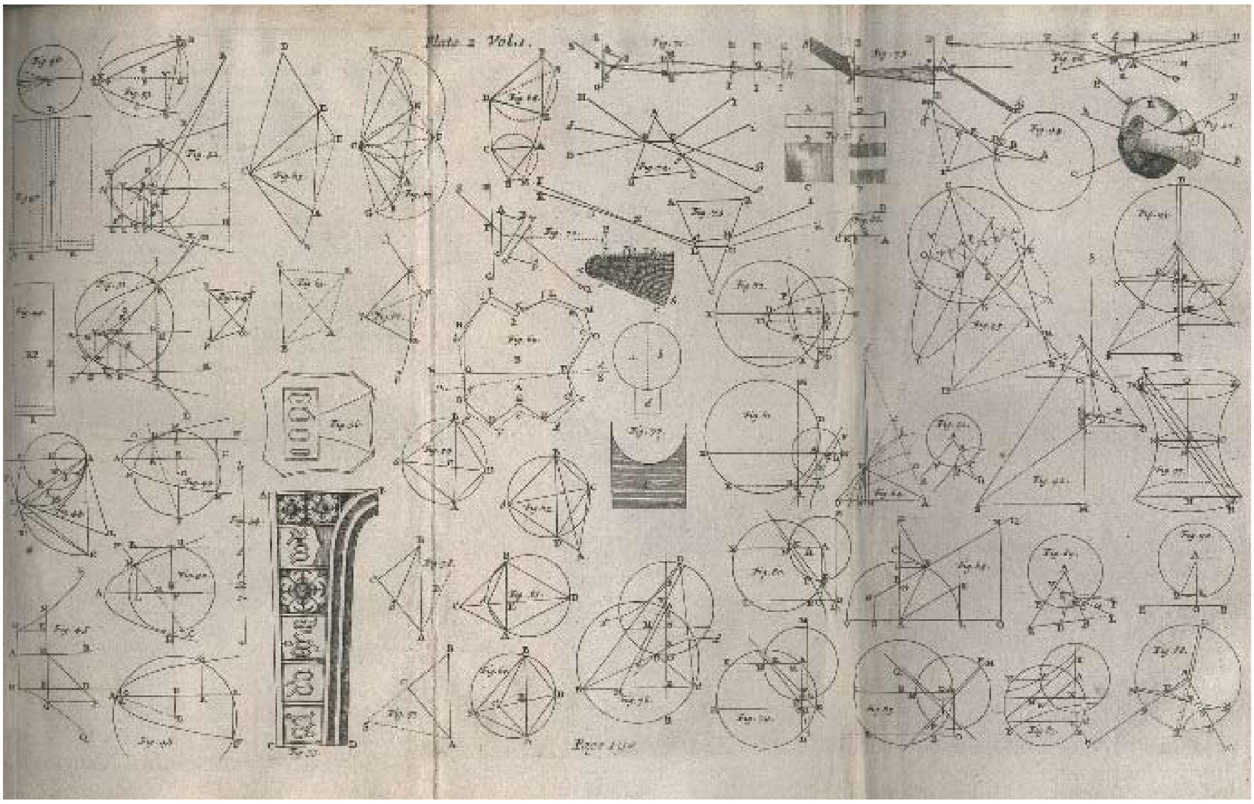
The work focused on the *Yuanxi Qiqi Tushuo Luzui*, the first monograph on western mechanics ever to be compiled in Chinese. In order to introduce this science to China, the authors of the *Qiqi Tushuo*, Wang Zheng (1571–1644) and Johann Terrenz Schreck (1576–1630), worked together on a Chinese presentation of western knowledge and machines from Archimedian times to the early seventeenth century, thereby merging the traditions of the two cultures. The *Qiqi Tushuo* has been made available on the Internet as a high-quality facsimile with introductory notes and as a transcription linked to a dictionary, together with further texts pertinent to the history of mechanics in China. This digital library on Chinese texts on mechanics is being further extended and has become part of the ECHO infrastructure (http://echo.mpiwg-berlin.mpg.de/content/chineseknowledge). Work on a commented English translation of the *Qiqi Tushuo* has been continued. In addition, a collection of essays on the history of mechanical knowledge in China and its interaction with western knowledge, comprising contributions by Partner Group members as well as by members of the Partner Group's advisory board and co-workers from the Institute, is presently being prepared. The essays deal with the concept of force in Chinese antiquity, the Chinese intellectual context of the *Qiqi Tushuo*, the introduction of the Galilean science of the strength of materials, through the Jesuit Verbiest, the influence of Western ballistics in Chinese treatises on artillery, and other subjects related to the transfer and transformation of knowledge.

The Parallel Cases of Optics and Music

The development of mechanics as the result of an interaction of practical knowledge with other forms of knowledge ranging from antiquity to the early modern period finds its parallels in the evolution of optics and music theory as fields of scientific knowledge similarly dependent on the accumulated experiences of practitioners. These parallel developments have in the context of the work of the department so far only been made the object of individual studies, in particular, on the role of the Camera Obscura as an optical instrument (Wolfgang Lefèvre), on Newton's *Opticks* (Volkmar Schüller), and on the development of the theory of proportions and its relation to musical practice and theory (Oscar Abdounur).

→ "Common Languages of Art and Science" p. 83

Isaac Newton, *Debate on Newton's New Theory about Light and Colors.* vol. I, pp. 128–172, 1716



Project 2

Reorganizing Knowledge in Developed Science: The Rise and Decline of the Mechanical Worldview

General Goals of the Project

→ for the role of experimental systems in such processes see also: "Generating Experimental Knowledge" p. 111

The goal of the project is the study of the emergence and dissolution of core groups of concepts that structure the vast knowledge embodied in the mechanical worldview as a result of processes of knowledge integration and disintegration. In the context of the project, the emergence of such a core group of foundational concepts is conceived as a restructuring of the cognitive organization of previously acquired knowledge. Core concepts of the mechanical worldview such as space, time, force, motion, and matter achieved their privileged position in the organization of knowledge only after a long process of knowledge integration in a material, social, and cognitive sense. Such concepts proved to be extremely stable in the face of an enormous growth of knowledge in the course of the further development of science. Nevertheless, physics, like many other scientific disciplines, has witnessed in the past century fundamental changes of precisely such core groups of foundational concepts. These fundamental changes were preceded by more or less extended periods of knowledge disintegration, in which the established cognitive organization of knowledge became problematic. Processes of integration and disintegration of knowledge are studied in close connection within the project since it has turned out that the essential mechanisms at work in periods of destabilization were of the same nature as those in the original processes of the emergence of core concepts of a discipline.

→ "A Cultural History of Heredity" p. 102

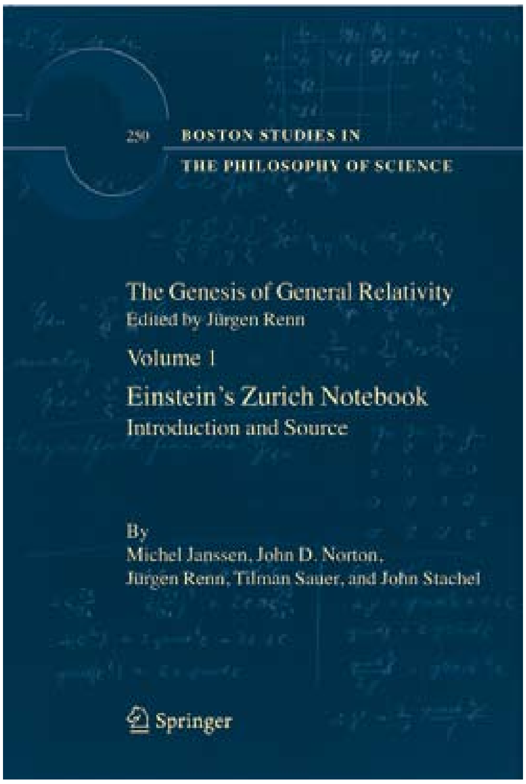
The project focuses on the history of the central mental models that shaped scientific thinking in the periods ranging from classical mechanics to the revolutions of modern physics and that challenged fundamental categories of mechanical thinking. It also traces the far-reaching restructuring introduced by the analytical tradition and disciplinary organization of scientific knowledge. The results already achieved for the emergence of the new concepts of space and time in the context of the two relativity theories are being complemented by similar research on the emergence of new notions of matter and causality established in the context of quantum theory.

The Relativity Revolution

As a result of a collaboration that extends over a decade a major four-volume work *The Genesis of General Relativity* (Michel Janssen, John Norton, Jürgen Renn, Tilman Sauer, Matthias Schemmel, John Stachel) has been published. It is based on a meticulous investigation of the relevant primary sources, which are reproduced together with detailed commentaries. The first two volumes analyze the interplay of physical and mathematical knowledge in the development of general relativity between 1907 and 1915. They provide, at the same time, a systematic account of the shared classical knowledge in which Einstein's theory is rooted. The second two volumes deal with the scientific context of Einstein's search for a new theory of gravitation, the largely unexplored history of alternative approaches to the problem of gravitation in late classical physics.

Apart from the conclusion of this major publication project, several other research activities were dedicated to investigating the relativity revolution, its preconditions and consequences. The transition from Newtonian mechanics of point particles to relativistic continuum mechanics was studied, focusing on major shifts in the categories for dealing with the motion of physical systems, in this case changes in such concepts as mass, force, and momentum (Michel Janssen and Matthew Mecklenburg). The ensuing paper, dealing with electromagnetic models of the electron proposed in the period 1895–1911, shows the central role of the electromagnetic view of nature, which competed with special relativity in its early days in this transition.

The Einstein Year 2005 offered an occasion for further scholarly activities dealing with the relativity revolution. The MPIWG co-organized the 7th Conference on the History and Foundations of General Relativity in La Orotava, Tenerife, together with the Fundación Canaria Orotava de Historia de la Ciencia and the Instituto Astrofísico de Canarias. Careful reviews of conceptual conflicts and a hitherto unique attempt to compare systematically the science of the universe in our times with the mechanical worldview at the beginning of the 20th century were at the center of the talks and discussions. A volume with selected papers from the conference will be published in the series *Einstein Studies*, edited by John Beckman, Christoph Lehner, and Jürgen Renn.



Cover of the four-volume work *The Genesis of General Relativity* (Ed. Jürgen Renn).

The department also co-organized the session "Einstein in Context" at the 22nd International Congress of History of Science 2005 in Beijing. In the session recent work on the cultural and intellectual contexts of Einstein was reviewed, ranging from studies of Einstein's relation to the Vienna Circle or to Henri Poincaré, via examinations of the reception of his work under politically diverse circumstances, to discussions of Einstein as a public figure and pop icon. A central event of the congress was the opening of the Chinese version of the exhibition "Albert Einstein: Chief Engineer of the Universe" prepared by the Institute (see below).

Also in the Einstein Year, a number of publications on Einstein's life and science have been prepared by members of the department, in addition to the books and papers directly connected to the Einstein exhibition. Among them are an edition of Einstein's *Annalen* papers that includes interpretative essays (Jürgen Renn), a comprehensive analysis of the structures of Einstein's relativity revolution (Jürgen Renn), a book on Einstein in Berlin (Dieter Hoffmann), a popular, best-selling biography (Jürgen Neffe) as well as a short biography (Dieter Hoffmann, Robert Schulmann), a book on Einstein's political and pacifist heritage (Reiner Braun), and a historical reconstruction of Einstein's scientific achievements in his *annus mirabilis* 1905 (Jürgen Renn, Robert Rynasiewicz). Some of these works have appeared under the umbrella of a newly founded series *Abenteuer Wissensgeschichte*, edited by Jürgen Renn. Other publications are in preparation, such as a book on the German Physical Society in the Third Reich (Mark Walker, Dieter Hoffmann), and a volume on Einstein in the *Cambridge Companions to Philosophy* series (Michel Janssen and Christoph Lehner). Furthermore numerous original sources have been made freely available online in the context of these activities, such as Einstein's *Annalen* papers <http://www.physik.uni-augsburg.de/annalen/history/Einstein-in-AdP.htm>.

A dissertation project is dealing with the opposition to the theory of relativity in the broader public in the 1920s (Milena Wazeck). It focuses on popular concepts of science and nature on which the critique of relativity is based and investigates both on an epistemological and a social level the struggle against modern physics as a process of the marginalization of popular knowledge claims. The dissertation draws on new source material from the papers of the fervent Einstein opponent Ernst Gehrcke (1878–1960) which the MPIWG recently acquired. Parts of the papers, including a newspaper article collection that contains around 3,000 articles on Einstein and the theory of relativity from the early 1920s, were digitized and made available within the framework of ECHO <http://echo.mpiwg-berlin.mpg.de/content/relativityrevolution/gehrcke>.

➔ "Knowledge and Belief" p. 61

The Quantum Revolution

As a continuation of the studies of the relativity revolution, the department has been preparing a research initiative dedicated to the history of quantum theory. The development of quantum theory since the early twentieth century has been one of the most complex shifts of foundational concepts in the history of physics. The ongoing discussions about the interpretation of quantum theory imply that we are still in the middle of this process. It presents a special challenge to the historian to work on shifting ground, but also makes the historical work highly relevant for the contemporary foundational debate in physics. The research initiative (co-ordinated by Christoph Lehner) was inaugurated with presentations on quantum dispersion theory in the mid-1920s just before the breakthrough to matrix mechanics by Heisenberg (Anthony Duncan, Michel Janssen). One central task of the planning process was to establish a network of historians, physicists, and philosophers to work together on a detailed analysis of central steps in the history of quantum theory. The search for collaborators has been successful, and contacts were established with institutions, archives, and individuals in the United States, the United Kingdom, France, Italy, the Netherlands, and Austria. A first meeting with over twenty scholars interested in an institutionalized cooperation was held at the MPIWG in June 2006. Parallel to this process, a cooperation was established with the Fritz Haber Institute of the MPG with the aim of establishing a center for the international network and publishing sources and review articles on the history of quantum physics. A joint proposal for funding this research initiative from the Strategic Innovation Fund of the President of the MPG has just been approved and granted. Among other things, the project aims to make historical key sources available on the Internet, e. g. the Archives for the History of Quantum Physics.

→ "Experimental History of Science" p. 143

→ "Knowledge Management at the MPIWG" p. 61

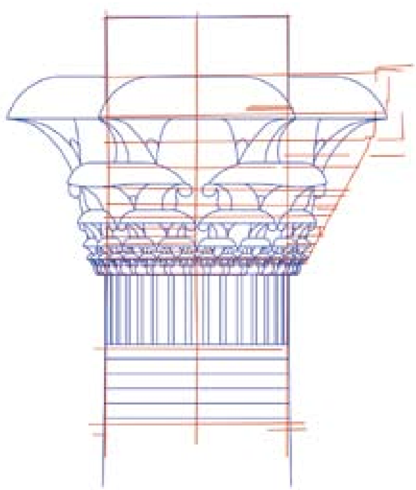
The research initiative also builds on earlier research undertaken at the Institute on the history of quantum theory (Giuseppe Castagnetti, Dieter Hoffmann, Horst Kant) as well as on ongoing work on statistical physics (Massimiliano Badino, Jürgen Renn). This research concerns the institutional context of quantum theory, and in particular the effect of contemporary scientists' recognition of quantum problems and their interrelations to the shifting of their research foci, reallocation of their resources, and reorganization of research structures and policies. A book project on the readjustments of research policies in reaction to the quantum crisis, which comprises two major studies, one on Einstein's role at the Kaiser-Wilhelm-Institut für Physik in Berlin, the other on Niels Bohr and his institute in Copenhagen has been completed (Giuseppe Castagnetti, Hubert Goenner, Alexei Kojevnikov).

Project 3

Epistemic History of Architecture

This project, a joint research endeavor with the Bibliotheca Hertziana, is dedicated to investigating the knowledge involved in architectural achievements from the first constructions of the Neolithic period to modern, science-based building technology. It thus comprises types of knowledge ranging from knowledge implicit in the rules of practitioners to scientific theories and technologies applied to the planning and realization of modern architecture. The aim is to reconstruct the systems of knowledge incorporated in the building process itself and their interaction with other knowledge systems. This reconstruction requires a broad approach in order to analyze geographically, chronologically, and culturally different forms of building processes, ranging from erecting a one-room dwelling to the construction management of complex monumental architecture <http://www.biblhertz.it/deutsch/forschung/wissensgeschichte.htm>.

A first major international conference within the framework of the project was held in 2003 at the Bibliotheca Hertziana and dedicated to early modern Italian architecture. The resulting volume is in press (edited by Hermann Schlimme.) A second workshop, dedicated to building traditions of the early cultures in Mesopotamia, was held in 2004 at the MPIWG (organized by Claudia Bührig.) Also in 2004, an exhibition and a workshop, co-organized with Bern University, dealt with the Hagia Sophia at Konstantinopolis/Istanbul, the most prominent architectural object to be realized in the centuries between late antiquity and the Middle Ages (Claudia Bührig, Volker Hoffmann, Wolfgang Lefèvre).



Architectural drawing of an Egyptian capital (red) in comparison to a finished capital (blue) from the temple of Edfu, around 100 B. C. The photo shows an unfinished capital from the temple of Philae from the same period.

Research in the early part of the project dealt with a broad variety of topics from different historical periods, ranging from neolithic architecture (Dietmar Kurapkat) via cuneiform sources related to the role of architects in ancient Mesopotamia (Blahoslav Hruška), the role of technical drawings from Mesopotamia to late antiquity (Claudia Bührig), to the early role of mechanical analysis in architecture, focusing on the work of Bernardino Baldi (Antonio Becchi).

At the end of 2005, there was a change in the MPIWG's side of the research team. Wilhelm Osthues, specialized in the architecture of Ancient Greece and Rome, is now directing the team, and Ulrike Fauerbach is working on the building trade in pharaonic Egypt. Under its new direction, the project team plans to publish, in co-operation with the Bibliotheca Hertziana, a collection of review articles and individual essays on key issues of an epistemic history of architecture, focusing on the neolithic period, Mesopotamia, Egypt, Greek and Roman antiquity, early Middle Ages in northern Europe, and the Italian Renaissance. The project will thus combine detailed case studies with a first attempt at a synthetic history of knowledge development in the realm of architecture.

The analysis of knowledge implicit in practice has further reaching significance. In a period in which the conflict-laden integration of traditional and industrialized societies no longer takes place on the level of colonial struggles, but on that of knowledge resources and value orientations, the understanding of systems of knowledge implicit in practice may be of vital interest for determining the role of science in this process of integration.

Project 4

The Globalization of Knowledge and its Consequences (in preparation)

The goal of the project is to study—focusing on specific research themes—conditions, pathways, and consequences of globalization processes of knowledge. The project is conceived as a multi-disciplinary and multi-national project in which smaller research groups from various countries participate. These research groups with specific, in part discipline-bound research goals form the core of the project. The collaboration of these research groups towards the common overarching aim shall be realized by workshops and a regular exchange of scholars.

According to preliminary discussions with potential partners of the project, the following thematic foci are emerging:

1 The spreading of culture in the Mediterranean area and neighboring regions;
2 Knowledge transfer among Europe, Middle East, India, and East Asia;
3 Transatlantic colonization and exchange processes; and
4 Culturally specific knowledge potentials and the import of globalized knowledge.

The planned project aims at integrating the results of specific research with a view to overarching questions concerning the conditions of knowledge transfer by persons, documents, and products, the mechanisms of the knowledge transformations induced by transfer and synthesis, as well as the conditions for the globalization of local knowledge. It builds on a variety of research activities that have so far been pursued independently and are now being integrated. Among these activities are the study of the invention of writing in various cultures (in the context of CDLI), of the transmission of European scientific knowledge to China by the Jesuits, pursued jointly with the Chinese partner group, of the exchange of knowledge by scientific voyages, pursued jointly with the Fundación Canaria Orotava de Historia de la Ciencia, and of the scientific and technological relations between Germany and Spain during the 20th century as an example for the export of scientific and technical knowledge and scientific organization models (Albert Presas i Puig). The ECHO initiative will provide an important empirical basis for studies undertaken in the context of the globalization project as it enables the comparison of sources from different cultures across the barriers of languages and media.
Some institutions, mainly in Europe, Asia, and Latin America, have already spontaneously decided to participate and have even offered financial support. Furthermore numerous potential partners have expressed serious interest in the planned project. In several discussions the intent to participate became clear, while funding possibilities have still to be explored.

FIG. 48. — Plateau du Guajara : la vue vers le Nord-Est.

Mascart, Jean. *Impressions et observations dans un voyage à Ténérife.* 1910

History of Science in Action: Public Outreach

General Goals

Based on the insight that scientific knowledge evolves as part of a comprehensive system of knowledge, new approaches to a public dialogue about science and its historical roots have been developed. These new approaches are distinguished by:

1. the representation of diverse worlds of knowledge that are subject to historical changes, along with the corresponding intellectual horizons of science and society as they evolve with these changes;
2. the representation of the multitude of premises for experiencing knowledge and science, taking into account the most diverse perspectives;
3. the representation of the diversity of the civilisatory and cultural spaces in which knowledge has developed historically, has been created or appropriated, and the communication between these spaces.

By introducing a historically informed perspective into the public discussion, the activities of the Institute have contributed to an awareness for the openness and plasticity of science, thus helping to overcome a polarized discussion shifting between the extremes of blind belief in progress and irrational hostility to science. Both positions are evidently based on the erroneous assumption that scientific progress is an automatism and not a historical process that can be shaped by mankind. If, however, science is connected by its very roots and not only *post factum* to other domains of society, unravelling these roots opens up opportunities for a new public understanding of science, relating it back to the sphere of human interventions. On this background, a new culture of science may emerge in which a public reflection on science can have repercussions on its cognitive and institutional structures.

The Einstein Exhibition

A new culture of science was at the center of discussions and outreach activities during the Einstein Year 2005, a common initiative of the Federal Government, science, industry, and culture. It celebrated the centenary of Einstein's revolutionary 1905 papers. A public understanding of science in its cultural and political contexts was also the focus of the large Berlin exhibition "Albert Einstein: Chief Engineer of the Universe," as well as of the extensive accompanying program and media activities surrounding it. The exhibition was inaugurated on 12 May 2005 by Edelgard Bulmahn, then Federal Minister of Science and Education


Inauguration of the Einstein Exhibition on 12 May 2005 by Edelgard Buhlmahn, then Federal Minister of Science and Education (left); explainers guiding tours at the Exhibition (right).

In 2003, a project group of the department (including Katja Bödeker, Elena Bougleux, Reiner Braun, Jochen Büttner, Giuseppe Castagnetti, Peter Damerow, Circe Dynnikov, Carmen Hammer, Dieter Hoffmann, Horst Kant, Christoph Lehner, Jürgen Renn, Simone Rieger, Matthias Schemmel, Sandra Schmidt, Michael Schüring, Urs Schoepflin, Ekkehard Sieker, Kurt Sundermeyer, Matteo Valleriani, Milena Wazeck) began to prepare the exhibition together with other Max Planck Institutes, international partners, an international and interdisciplinary scientific advisory board, exhibition makers (Stefan Iglhaut and his team), and media representatives. A close cooperation with the Hebrew University of Jerusalem, the Deutsches Museum München, and the University of Pavia, and cooperation with the Federal Ministry for Science and Education as well as funding by the Kulturstiftung des Bundes, the Ministry, the Heinz-Nixdorf, the Robert-Bosch, and the Klaus-Tschira Foundations as well as other foundations, firms such as BASF and SIEMENS, and partners, such as DESY and CERN, laid the foundations for the success of the exhibition.

Children visiting the Einstein exhibition.

From 16 May to 30 September 2005 more than 130,000 visitors experienced the exhibition as a highlight of the Einstein Year. Staging the history of science as an adventure of discovery and struggle for knowledge, the exhibition succeeded in reaching a broad public. It was particularly acclaimed by younger visitors. More than 10,000 students and children participated in guided tours or in workshops held at the exhibition.

The Einstein exhibition at the Kronprinzenpalais in Berlin.

The goal of the exhibition was to take the life and science of Albert Einstein as a guide for illustrating the historical change of scientific worldviews and the development of science in a broadly understandable way. Einstein's biographical path was set in the context of the political and social cataclysms of his time. By connecting history of science and history of culture, visitors were offered a perspective on Einstein's biography that transcended the traditional image of an ingenious and exceptional scientist. Scientific knowledge was not offered as a collection of rigid facts but as part of a dynamical, multi-facetted cultural process. Indeed, it was not the exhibition's primary aim to provide fixed answers, but rather to encourage the visitors to question and interact with the contents of the exhibition. The representation of historical worldviews and the reference to present challenges of the sciences animated the visitors to develop their curiosity, to discover the cultural dimension of scientific knowledge, and to address questions about the social and political significance of scientific research.

Media of Science Communication

The wide range of scientific and cultural themes of the exhibition as well as its pedagogical intentions represented challenges that were addressed with the help of diverse approaches of science communication, ranging from the creation of historical ambientes and of artistic stage settings via the employment of multimedia, a pedagogical program that included explainers, guided tours, and special workshops, to the publication of a three-volume catalogue representing, at the same time, a high-level popular introduction to the history of science as pursued at the Institute.

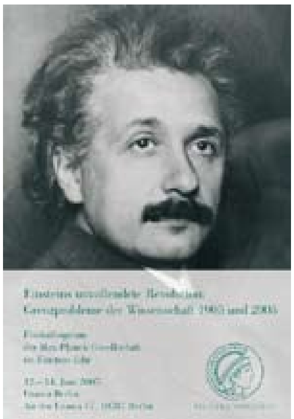
Concerning the use of multimedia technology, the exhibition project developed new approaches, for instance, combining historical objects with interactive electronic media in the exhibition and, at the same time, enabling access to the exhibition contents via a virtual exhibition freely available on the Internet <http://www.einsteinausstellung.de>. Even after the closure of the Einstein exhibition, the virtual exhibition continues to offer, with more than 1,000 continuously extended and updated pages, a living panorama of the history of science that is useful as a learning and teaching tool but also as a resource for the history of science, and that guarantees the long-term availability of the contents assembled for the exhibition. In the exhibition, original historical instruments such as a Leyden jar were accompanied by computer animations that allowed an interactive exploration of the way they function. Furthermore, special films were produced showing fictive dialogues among historical personalities illustrating, for instance, the crisis of physics around 1900. Einstein's reaction to this crisis and his attempts at solving it have also been made the subject of such films. As will be explained in more detail below, approximately 50 media stations distributed all over the exhibition—and at the same time accessible via the Internet as part of the virtual exhibition—offered the visitors different ways of consulting additional information resources about the exhibits, or of participating in quiz games that encouraged children in particular to learn about the exhibits in a more playful manner. In the exhibition, the media stations, which also contain virtual exhibits such as historical films, audio material, or live transmissions from research institutions, became meeting points for spontaneous seminars among the visitors.

The catalogue of the exhibition actually represents a compendium of the history of science that focuses on changes in scientific worldviews as they were characteristic of Einstein's revolution. It consists of three volumes: The first volume closely follows the narrative structure of the exhibition; the second volume assembles more than 100 essays on the historical background of Einstein's life and work as well as on related issues of current research; the third volume offers a comprehensive documentation of original sources reproduced as high-quality facsimiles, setting Einstein's biography in the context of his times. In addition, a DVD with video and audio material from the exhibition was published, serving as a complementary resource to the virtual exhibition and as a tool for science education and popularization.

Accompanying Program

The Einstein exhibition was accompanied by a program of scholarly and public events which connected its themes with the wider discourse on science and its contexts in the Einstein Year. For the Institute, this accompanying program was an opportunity to present the results of its research projects in a new ways and to extend its network of collaborations including media partnerships with TV and radio channels, newspapers, journals, and magazines. The program addressed a broad variety of age and interest groups and comprised public lectures, theatre plays, cinematographic events, round-table discussions, TV and radio events, newspaper and journal contributions, summer camps for students, international school conferences with students from Poland, Switzerland, Italy, and Germany, children's events, etc. One of the highlights of the accompanying program was an interdisciplinary lecture series, entitled "Einstein Lectures," co-organized with the three Berlin Universities and the Young Academy of Sciences in Berlin, and attended by more than 2,500 participants.

The "Einstein Lectures," held at the Berlin-Brandenburg Academy of Sciences (right), and the cover of the DVD with the collected lectures of the celebratory colloquium "Borderline Problems of Science 1905 and 2005" (left).



Of the Institute's many contributions to the Einstein Year, five major scientific conferences deserve a special mention: the 22nd International Congress for the History of Science in Beijing; the 7th International Conference of General Relativity in Tenerife mentioned previously; the international conference "Discovery, Creativity and Innovation. Einstein's *annus mirabilis*" in Bern, co-organized by the MPIWG together with the University of Bern; the international conference "Einstein and Europe" in Düsseldorf, co-organized by the MPIWG together with the Wissenschaftszentrum Nordrhein-Westfalen and the Royal Netherlands Academy of Arts and Science, focusing on the framing conditions for science after Einstein; and the celebratory colloquium "Borderline Problems of Science 1905 and 2005" organized by the Institute on behalf of the MPG at the Berlin Urania Congress Center.

Both the exhibition and the accompanying program were embedded in a network of international co-operations. The international partners of the exhibition, for instance, had the opportunity to present their contributions during special events such as the "Italian Night" or the "Chinese Night." These events also served to introduce the parallel versions of the exhibition that were shown in China and in Italy and that are being prepared for inclusion in the virtual exhibition. The Berlin exhibition team furthermore supported other Einstein exhibition projects, such as an Einstein exhibition in Potsdam and another in Japan. Close co-operation with the Hebrew University of Jerusalem, in particular with the Albert Einstein Archives, made it possible to display, document, and analyze the uniquely valuable original documents from its holdings. The co-operation with media partners of the exhibition enabled the Institute to build up a collection of interviews with contemporary witnesses. Finally, co-operations with a wide network of research institutions, ranging from other Max Planck Institutes to research centers such as DESY and CERN, not only created the presuppositions for addressing issues of current science in the exhibition, but also continue to serve as important reference points for the interdisciplinary research projects of the department.

History of Science in Action: Development of Electronic Research Tools and Databases

General Goals of the Developments

Recent developments in electronic data processing have fundamentally changed the potential of research in the history of science as well as in other disciplines. The electronic storage of historical sources improves their accessibility and makes new and powerful methods of retrieving of information possible. Scanning and optical character recognition techniques are being used to build electronic archives of historical sources, and databases and software tools are being developed to assist research and editorial activities. These activities aim at the creation of working environments that allow the integration of historical details into coherent models of historical developments. They are based on both the availability of a wide range of sources accessible to the scientific community as a whole, within the framework of open digital research libraries, and on scholarly cooperations extending well beyond a single institution. These cooperations, characterized by a novel unity of research and dissemination, are by their very nature international and interdisciplinary. They draw on the potential of the World Wide Web to cut across the traditional distinctions of research institutions, universities, and libraries.

➔ "Knowledge Management at the MPIWG" p. 161

The Cuneiform Digital Library Initiative as an Example for an Open Digital Research Library

The Cuneiform Digital Library Initiative (CDLI: Jacob Dahl, Peter Damerow, Robert Englund) represents the ongoing efforts of an international group of Assyriologists, museum curators and historians of science to make freely available through the internet images and content of cuneiform tablets dating from the beginning of writing, ca. 3350 BC, until the end of the pre-Christian era. The number of these documents currently kept in public and private collections is estimated to exceed 500,000. More than 175,000 of these have now been catalogued in electronic form by the CDLI.

In its early phases of research, the project concentrated on the digital documentation of the least understood archives of ancient cuneiform, those of the final third of the fourth, and of the entire third millennium BC that contained texts in Sumerian, in early Akkadian and in other, still undeciphered languages. Despite the 150 years since the decipherment of cunei-form, and the 100 years since Sumerian documents of the third millennium BC from southern Babylonia were first published, basic research tools such as a reliable paleography charting the graphic development of archaic cuneiform, and a lexical and grammatical glossary of the approximately 120,000 texts inscribed during this period of early state formation, remain unavailable even to specialists, not to mention scholars from other disciplines for whom these earliest sources on social development represent an extraordinary hidden treasure.

The CDLI data set consists of text and image, combining document transliterations, text glossaries and digitized originals and photo archives of early cuneiform. At present, the online catalog of the CDLI contains more than 175,000 catalog entries with information about tablets of the third millennium B.C., more than 16,000 digital images of these tablets, more than 41,000 hand copies, and more than 56,000 transliterations, all of which are accessible through the CDLI web site. This electronic documentation should be of particular interest to scholars distant from collections, and to museum personnel intent on archiving and preserving fragile and often decaying cuneiform collections.

In 2005 the CDLI made a concerted effort to include target text-groups from the 2nd millennium BC in the project's core set of data. Two texts groups were chosen for this first stage, the Middle Assyrian texts (ca. 2,000 texts dating to 1400–1100 BC), in cooperation with Professor Dr. Eva Cancik-Kirschbaum from the Freie Universität Berlin, and the Old Assyrian texts (ca. 22,000 texts dating to 1900–1800 BC), in cooperation with the Old Assyrian Text Project (Copenhagen). In addition to continuing digitization work in the Vorderasiatisches Museum, Berlin, and in minor European and North-American collections, the CDLI has begun, in a joint effort with staff from the Oriental Institute of the University of Chicago, to digitize and catalog the collection of about 8,000 cuneiform tablets housed there.

Royal inscription from the Ur III period (ca. 2100–2000 BCE), commemorating the construction of a temple of Inanna by the king Shulgi. (Birmingham City Museum, Birmingham, U.K., Museum no.: A.3104_1982)

From Browsers to Interagents

The current paradigm of the web—in which the user browses, leaving behind a click-trail that is of interest primarily to marketers—falls far short of the needs of scientists and scholars. Browsing the web is scarcely more interactive than surfing television channels. True interactivity—which will allow the web finally to achieve its potential as a medium for scholarly, political, and social dialogue—demands something other than the current browser/server paradigm. New tools will be needed, whose developers recognize that information consumers are also information producers. Scholarship is an inherently recursive activity, in that the scholar uses existing scholarship to produce new scholarship. Knowledge undergoes a process of accretion, akin to the formation of a pearl; one exemplary model is a page of the Talmud, on which there is a hierarchical arrangement of commentary, super-commentary, annotation, and cross-reference that spreads from center to margin.

Although information production (and not just consumption) is beginning to emerge in the current web—consider such examples as Wikipedia—and will surely grow in the new paradigm referred to as "Web 2.0," true interactivity demands a new tool: not a browser, but an interagent or "knowledge weaver." With these ideas in mind, for the past few years, researchers in the department have been developing a prototype interagent called Arboreal (Malcolm Hyman). Arboreal allows for flexible, non-linear navigation of arbitrary XML documents and for granular annotation of these documents down to the word- or term-level, and is at present used extensively by the research projects of the department, e.g., in the context of the CDLI and the co-operation with the Chinese Partner Group. Annotations themselves are XML data, which can be shared, published, and further annotated in turn <http://archimedes.fas.harvard.edu/arboreal/>.

Since information is transmitted through the medium of language, Arboreal integrates linguistic technology through extensible components and web services. Language support is critical to the increasingly global enterprise of science, where researchers collaborate across barriers that are not only geographic but also linguistic. Language support includes not just display—although flexible options are needed for different scripts and transliterations—but also the identification of words, lemmatization and morphological analysis, and dictionary lookup. These are critical and basic functions that will serve as the foundation in the future for a richer set of facilities, including term and keyword discovery, language-neutral searching based on concepts rather than words, automatic summarization, and sophisticated semantic linking.

The historical materials studied at the Institute—which include manuscript and printed materials in diverse ancient languages—pose special problems. Arboreal and related web services have been developed for dealing with Latin, ancient Greek, classical Arabic, classical Chinese, and major languages of modern Europe (Italian, German, English, Dutch, French). Collaboration with the Pennsylvania Sumerian Dictionary project has recently added support for Sumerian, and Akkadian is in development; collaboration with the NSF-funded project International Sanskrit Digital Library Collaboration (Brown University, CEDAR/SUNY Buffalo, University of Frankfurt, University of Cologne) will yield support for Sanskrit. Current research aims in adding technologies to deal in addition with the formal languages used in such fields as mathematics, physics, and chemistry.

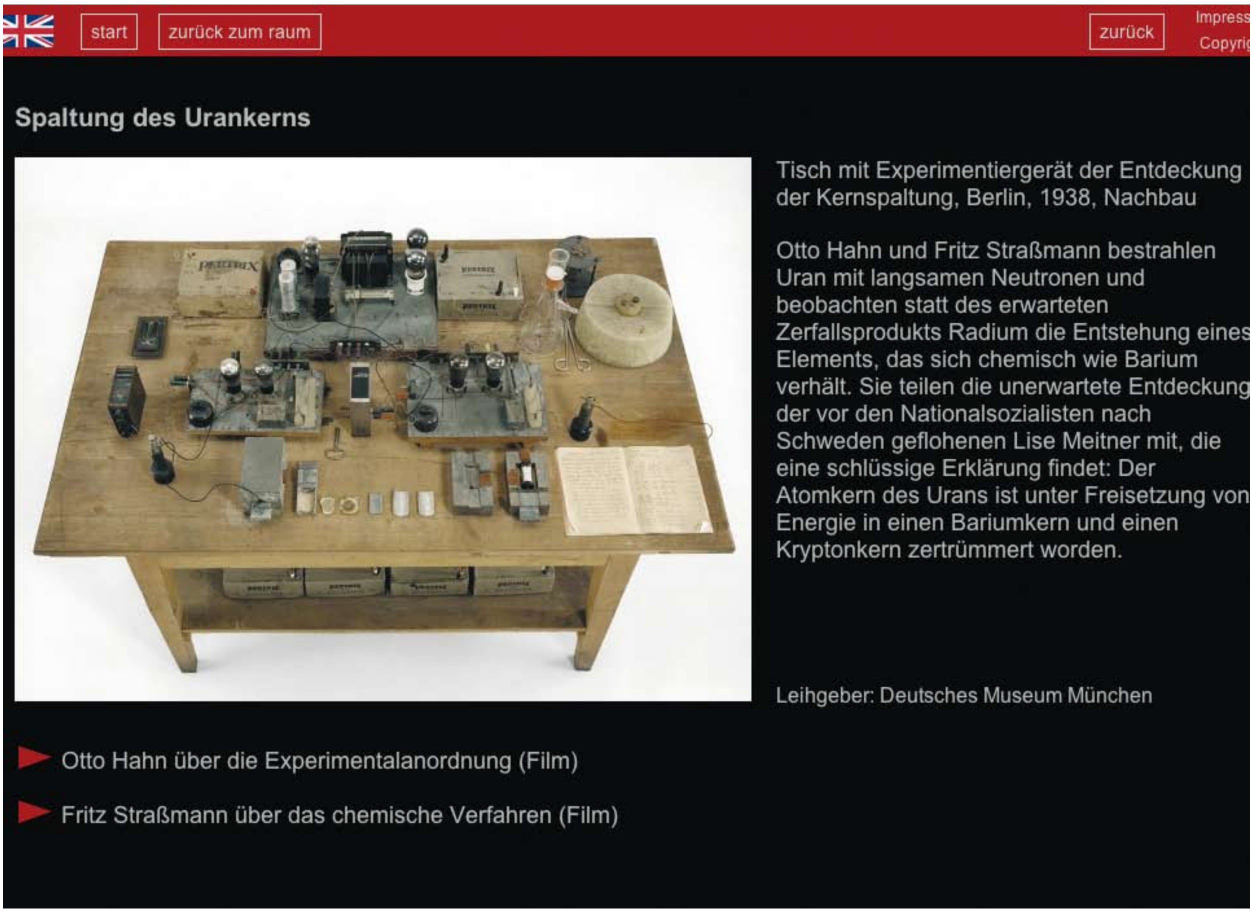
A Virtual Exhibition as a Medium for Spatially Organizing Knowledge

With the exhibition "Albert Einstein: Chief Engineer of the Universe" in 2005, the Max Planck Institute pioneered, with major financial support from the Heinz Nixdorf Foundation, Siemens, and BASF, a new concept: an "exhibition without walls" (Peter Damerow, Malcolm Hyman). As mentioned above, within the exhibition space of the Kronprinzenpalais were approximately fifty interactive touch-screen-based "media stations." The media stations provided further information on the objects and documents displayed, as well as detailed historical and scientific explanations related to the exhibition content. A number of media stations provided not only interactive content aimed at adult visitors, but also special content targeting children. Rich content available on the stations included video, animations, photographs, drawings, cartoons, scanned documents, text, and external data from the World Wide Web. The media stations brought the larger world of digital media into the Kronprinzenpalais, but at the same time computer servers at the Institute made the content of the exhibition available to a worldwide audience as a virtual exhibition <http://www.einsteinausstellung.de/>. In the virtual exhibition, which is intended to be permanent, visitors can navigate a virtual space corresponding to the exhibition at the Kronprinzenpalais, view photographs of objects and vitrines, explore 3D panoramas of the rooms, and access all the content available on the interactive media stations.

In developing the virtual exhibition, the Institute maintained its strong commitment to Open Access (as articulated in the Berlin Declaration) and the Open Source Software movement. Servers ran an open source operating system (Linux), as well as an open source web application framework (Zope) created in an open source language (Python). Software on the media stations was also entirely open source, including the operating system (Linux) and kiosk-mode browser (Firefox, with modifications by the MPIWG). All software developed by the Institute for both clients and servers is made publicly available under an open source license (Robert Casties, Malcolm Hyman, Dirk Wintergrün).

Fundamental to the design of the virtual exhibition software is the identification of three roles: programmers (individuals who develop and extend the software infrastructure), graphic designers (individuals who develop templates and layouts for information display, with attention to fonts, colors, aesthetics, and perceptual psychology), and content creators (scientists who assemble the multimedia content and compose text). In the virtual exhibition model, these roles are maximally independent. Content creators do not need to be concerned with design or technical implementation issues, and graphic designers do not need detailed knowledge of either the underlying software or the historical/scientific content. Work proceeds in a networked environment where content creators can easily use a web browser to create "slides" with textual content as well as image and video content that is hosted in a shared project-wide web-accessible database. At the same time, designers develop templates that match the general aesthetics of the exhibition; these templates immediately become available for content developed by the scientists and researchers.

Currently the Institute is working with other partners to implement the virtual exhibition model elsewhere. Pilot institutions include the Università degli Studi di Pavia, the Fundación Canaria Orotava de Historia de la Ciencia, and the museum of science (UNIVERSUM) of the National Autonomous University of Mexico (UNAM). As museums and other institutions produce content with the virtual exhibition software, a "virtual world of exhibitions" will emerge, which will truly transcend the barriers of geographic space by making museum and exhibition content anywhere in the world available to any user who sits in front of a computer with a standard web browser. A virtual exhibition, however, may open up an even wider perspective towards new possibilities of organizing knowledge according to a spatial metaphor, allowing, for instance, information on animals and plants to be placed in the context of a virtual reproduction of their natural habitats, or to situate knowledge on archeological objects in the context of a virtual reproduction of excavation sites, so that such knowledge can be interactively and dynamically accumulated in a way similar to the Wikipedia model.



Media station and part of the virtual Einstein exhibition.