**Status of Instruments:**

**Speakers are:**

**1 Dr. Jim Bennett (keynote speaker)**
Museum for the History of Science, Oxford, United Kingdom
**An Introduction to Instruments and Identities**

**2 Prof. Eileen Reeves**
Comparative Literature, Princeton University, Princeton NJ, USA
**Real Fakes: Perspective Glasses Onstage, 1590-1608**

Over a decade ago scholars sought to establish the existence and nature of the so-called "Elizabethan telescope," a primitive optical instrument involving a lens and mirror combination, and seemingly available in England from around 1570 onwards. Of modest value, the conjectural device appears to have excited a great deal interest among philosophers and instrument makers than military men and rulers, and disappeared almost entirely with the advent of the refracting telescope in September 1608. That said, there is evidence of this instrument (or instruments) elsewhere: there was analogous experimentation with lens-and-mirror combinations in the Veneto in the latter part of the sixteenth century, and an invoice of 1599 from the Chambre des Comptes of Lille for l'achapt fait de trois voirres perspectives pour le service de leurs dictes Altezes indicates that the rulers of the Spanish Netherlands paid for some sort of telescopic device, though there is no guarantee, of course, that the glasses actually functioned as promised.
One important source of information has been overlooked by scholars interested in this question: extant English literary works, particularly comedies, offer a wealth of references to "perspective glasses," "glasses perspective," and "perspectives" from 1590-1608. Apart from Colin Ronan's allusion to Robert Greene's reliance on the optical device as a prop in a play of 1590, there has been no sustained discussion of the onstage appearance of such instruments, and no attention to what the original audiences would have understood of them. However flawed and difficult to use these perspective glasses were-defects acknowledged and even exploited in several plays-their regular appearance in literature and onstage signals a certain familiarity and dramatic efficacy. While the status of the instruments is complicated by the fact that they are sometimes handled by villainous characters and that they appear and are meant to function in the realm of theatrical illusion, certain features of these optical props replicate what John Dee, Leonard Digges, and William Bourne had written of the devices in the somewhat more sober works a decade or two earlier: they all seem to involve reflection rather than refraction, they offer a relatively small field of view, and they produce enlarged images that come in and out of focus and are subject to chromatic aberration. While it would be simplistic to view the discussions of perspective glasses in the works of Dee, Digges, and Bourne as especially accurate or realistic, and their exportation to the stage as a timely confirmation of the instrument's eventual success, to judge from extant texts one can chart a change in the status of the device from its original association, in two plays of the early 1590s, with necromancy and the inevitable Friar Bacon, to its appearance as the unwieldy tool of the braggart soldier, an obscure governor, and foolish philosophers and rapacious explorers by the end of the decade and beginning of the next. At no point, not even in its occult guise, is the perspective glass entirely freed from buffoonery, and the fact that this constant subtends a number of otherwise dissimilar dramas may suggest that the unreliability of the instrument was exploited onstage.

Attention to these texts has one further benefit: they constitute a relatively coherent corpus, and even a dialogue of sorts about the use of the perspective glass onstage. Though my argument touches upon ten different texts, I would like to pay particular attention to five works by three different writers whose engagement with each others' work was constant, if not always favorable: Robert Greene, the man whom he christened that "upstart Crow beautified with our feathers," William Shakespeare, and Robert Armin, the most talented clown of Shakespeare's troupe, but also a playwright himself. While the absence of explicit stage directions and audience reactions to the deployment of these props is regrettable, the fact that the perspective glass appeared and reappeared in closely watched theatrical venues over the course of these years suggests that it was for playwrights and audiences alike an object both familiar and wondrous, and a "real fake" as a dramatic device.

**3 Dr. Huib J. Zuidervaart**
Independent scholar, The Netherlands

**Scientific Instruments & Observations as a Vehicle for Social Status. The Case of Pieter Gabry F.R.S. (1715-1770)**

The eighteenth century was an era in which the phenomenon of the ‘gentleman-scientist’ arose: a layman without scientific education who, for a variety of often socially desirable reasons, devoted himself to scientific endeavours. Science appeared to be a useful vehicle to acquire prestige and social status. Scientific instruments were the tools to the observations, which enabled some ‘gentleman-scientists’ to become a member of the scholarly European ‘republic of letters’.

We will demonstrate this use of science with the case of Pieter Gabry (1715-1770), a Dutch lawyer, born in the East Indies, who from 1745 onwards proclaimed himself as ‘Physicus, Mathematicus & Astronomus Hagae-Comitum’ [=physician, mathematician and astronomer of The Hague].

Gabry used his cabinet of scientific instruments to perform public experiments, with which he made the impression on his lay audience to be something like an academic professor. Starting in 1746 he also performed meteorological and astronomical observations, which he used to become a member of several respected international scientific bodies, such as the Royal Society of London, the Académie Royale des Sciences de Paris and the Societatis Regiae Scientiarum Gottingensis. In 1756 however he was exposed in the Netherlands as a plagiarist and a ‘decorator of observations’. This affair forced him to resign as a member of the Hollandsche Maatschappij der Wetenschappen (= Dutch Society of Sciences). However, outside the Netherlands this demise remained unnoticed, and as Gabry continued until 1768 to publish a yearly broadsheet in Latin with an overview of his meteorological and astronomical observations, this enabled him to continue his ‘learned’ correspondence with several European scholars, such as Wargentin, Mendes da Costa, Le Monnier, Hamberger, and others. However, in personal contact, Gabry apparently was quickly valued in the right perspective: when in 1759 the Swedish astronomer Bengt Ferrner visited Gabry’s cabinet of scientific instruments, he put as an entry in his diary: ‘Gabry certainly would be more honourable when he did not try to appear more then he really is’. So, at the end of the day the content of science prevailed over its context.

**4 Dr. Karsten Gaulke (keynote speaker)**
Astronomisch-Physikalisch Kabinett, Staatliche Museen Kassel, Germany
**Some New Looks on the Astronomical Instruments and Clocks of Wilhelm IV of Hesse-Kassel**

Until now the famous "Wilhelmquadrant" and the "observatory-clocks" of Jost Bürgi are known as important witnesses of the astronomical work on Kassel observatory in the 16th century. However recent researches have shown, that some old interpretations are at least partially questionable or incomplete. In particular the clocks of Bürgi are not at all remains of the observatory and the "Wilhelmsquadrant" came to life again in a very interesting context at the beginning of the 18th century.

**5 Prof. Dr. Frans van Lunteren**
Institute for the History and Philosophy of Science, Utrecht University/Vrije Universiteit Amsterdam, The Netherlands
**'Beati possidentes': the Royal Dutch Academy and the Standard Metre**

In 1887 the Science Division of Royal Dutch Academy faced a crisis. A bitter conflict between two of its most prominent members endangered the Academy's carefully cultivated image of dignity and unity. The bone of contention, trite as it may seem, was the proper repository of a metal bar, the prospective Dutch standard metre. J. Bosscha, the dean of Dutch physics, director of the Delft Polytechnic and head of the Committee for the Standard Metre and Kilogramme had stored the commissioned copy of the French prototype in Delft, much to the chagrin of the renowned physiologist F.C. Donders, former president of the Academy's Science Division.
In Donders's view the Academy (based in Amsterdam) held historic rights to standards. Ownership of the standard, moreover, appeared to him to be vital to the Academy's role, especially as it sealed its relationship with the state. He accused Bosscha of encroaching on the rights and interests of both Dutch science and the Academy. Bosscha, for his part, stressed the need to keep the instruments at the place where they were used for practical purposes by metrologists, in other words at Delft. As he made clear, his own view of the proper role of the Academy differed strongly from that of Donders.
In a sense a national prototype is the ultimate instrument, or the instrument that measures all other instruments of a similar nature. At a time of both rapid industrialization of Western societies and professionalization of Western science, precision and uniformity became highly valued characteristics, representing both scientific and, to an ever greater extent, commercial interests. Accordingly the responsibility for the use and preservation of standards could assume a symbolic meaning that far exceeded its practical importance. In this talk I will give a brief account of the controversy and analyse the different issues at stake.

**6 Dr. Sven Hauschke**
Germanisches Nationalmuseum Nürnberg, Germany
**Scientific Instruments and the Invention of the Renaissance "Kunstschrank"**

The renaissance "Kunstschrank", a piece of furniture developed out of a transportable writing cabinet, was created to house precious objects, which had been formerly kept in the "Kunstkammer" or art chamber of princely patrons - the forerunners of modern museums. The invention of the "Kunstschrank" is widely ascribed to Philipp Hainhofer (1578-1647) from

Augsburg, a famous patrician who acted as diplomat, art consultant and collector. He organized the work of various craftsmen to create a new type of furniture. Four of these "Kunstschränke" had been made. The best documented samples are the one sold to Duke Philipp II of Pomerania and known as the "Pommersche Kunstschrank", which was destroyed in 1945, but whose contents has been preserved in Berlin and the one given to King Gustav Adolf of Sweden in 1632, which survived at Uppsala. Both cabinets had been handed over by Hainhofer together with a detailed description of their function and contents.
The most valuable part of a "Kunstschrank" was its enclosed collection, which represented as "naturalia" and "artificialia" the whole cosmos. In a "Kunstschrank" works of art made out of different materials like silver, brass, bronze, iron, ivory, bone or wood were being kept next to natural history specimens as minerals or zoological items. An important group of objects were the various scientific instruments, which can be interpreted as a kind of link between man-made objects and nature, because with their help nature could be measured.
The paper will discuss the idea and concept of the "Kunstschrank" with respect to the integration of scientific instruments. Further the origin of the "Kunstschrank" will be examined regarding the role of other caskets containing scientific instruments.

**7 Dr. Sophia Vackimes**
New School University, New York, USA
**Of Science In Museums: Postmodern Cabinets of Curiosity**

In laboratories some facts are reified as scientific knowledge, while others are discarded; in like manner science museums help transform a public quest for information into culturally and socially acceptable ways of grasping nature, the work of scientists, and the advancement of knowledge. Following postmodern trends and aesthetics, museums act as social laboratories where “enhanced environments” help set up correspondences between natural orders and contemporary social needs. However, as objects in them are detached from their natural environments and converted into signifiers of discrete elements of knowledge, ideological narratives of progress and power are configured. Usually “Big Science,” the science heir to the traditions of nuclear weaponry and genetic engineering, is presented to the public as a superior kind knowledge. When exhibited as such it engages public perceptions in specific manners. It is not devoid of agency, or of specific political and cultural aims.
This cross-cultural analysis draws attention to a specific set of tools historically developed and deployed to convey notions of power and progress. A view of scientific iconography—and in particular cabinets of curiosity—traverses institutions in the United States, Great Britain and Mexico to exemplify the dominant exhibitionary paradigms of contemporary museologic exhibitionary practices. In this manner the demarcation between science and technology, the erasure of alternate ways of knowledge and the erosion of “scientific truth” and the “ethical boundaries of science” are herein considered.

**8 Françoise Le Guet Tully and Jean Davoigneau**
Observatoire de la Côte d’Azur, Nice, France
Direction de l’Architecture et du Patrimoine, Ministère de la Culture, Paris, France
**The 19th-Century Observatory Today: From an Astronomical Instrument to a Cultural and Scientific Symbol**

The first modern astronomical observatory is the one which Wilhelm Struve erected in the 1830s at Pulkovo, near Saint Petersburg, at the request of Czar Nicolas I. Until the middle of

the 20th century, dozens of observatories were built all over the world along this model: a carefully chosen site equipped with good equatorial and meridian instruments sheltered in well adapted buildings positioned on the site according to a specific layout. Today, as far as astronomical observations go, nearly all these observatories are obsolete. Considering the observatory itself as a scientific instrument, we shall discuss how each of the criteria mentioned above-site, instruments, buildings, layout, etc.-can be used to explain basic (or less basic) astronomical concepts to the general public, as well as recent developments in observational astronomy. Hence a proposal, amongst others, for the future use of these sites and their material heritage: a progressive transformation into cultural symbols of astronomy and science.

**9 Prof. Dr. Bjørn Ragnvald Pettersen**
University of Environmental and Life Sciences, Department of Mathematical Sciences and Technology, Ås, Norway
**Astronomy in a Shipping Nation: Harbour Observatories in Norway 1857-1900.**

Between 1857 and 1900 there were four astronomical observatories in Norway servicing the needs of shipping in their respective harbours. Three facilities were operated exclusively for the purpose and the fourth was the university observatory in the capital. They were equipped with transit instruments aligned with the local meridian, and a pendulum clock to record time. Their task was to provide astronomically determined time for chronometer control and weekly time ball signals. The observatory personnel had a wide range of educational background and included academically trained astronomers and professors, navy officers, local clock makers, and a primary school teacher. Their focus ranged from carrying out the specified task, via experimental testing and development of new technologies, to academic research. Some institutions were lead by one competent individual for decades while others had a string of part time observers. The variety of local conditions led to very different scopes and scientific achievements for each observatory. Two were able to contribute to research as measured by papers in international and national science journals. One was initiating and leading experiments to implement time transfer by telegraphy for accurate determination of longitude differences between observatories. One observatory remained a local time facility and never contributed to R&D. We discuss the individual achievements and relate them to the basic skills, ambitions, and science interests of each observatory leader.

**10 Pedro Ruiz-Castell**
Department of Research and Documentation Museo Nacional de Ciencia y Tecnología, Madrid, Spain
**Scientific Instruments for Education in Early Twentieth-Century Spain**

The crucial point of the end of century crisis in Spain was the year 1898. The military defeat of that year in the Spanish-American War was seen as evidence that the country was in terminal decline. The aims of regeneration spread throughout various sectors of Spanish society and the State became more and more interested in supporting and sponsoring science and technology, as well as creating an appropriate educational system. Consequently, the first decades of the twentieth century were a turning point in the development of science and technology in Spain. Several reforms were promoted and a strong interest in scientific education was exposed. Some works have shown during the last years different initiatives taken by Spanish governments in this direction, particularly with the creation of new official

institutions. Scientific instruments were needed not only to improve Spanish scientific research but also to improve the teaching of experimental sciences. They were specifically adapted to be used by students. The new institutions played an important role in the development of science and technology, but their activity in the promotion of scientific education was very limited. This paper aims to present some of the unknown names of individuals and firms who, in a new social and cultural context, provided scientific instruments to educational centres in order to overcome the increasing demand for this material by Spanish institutions during these years. Some of these instruments are found in the collection of scientific instruments of the Spanish National Museum for Science and Technology in Madrid.

**11 Dr. Sven Dupré & Dr. Michael Korey**
Centre for History of Science, Ghent University, Belgium and Mathematisch-Physikalischer Salon, Dresden Art Collections, Germany
**The Use and Re-Use of Optical Instruments**

In the second half of the sixteenth century a Kunstkammer was established in Dresden. What later came to be recognized as scientific instruments; were collected here as part of this courtly collection. Many of these objects seem to have been connected to the personality and the political and economical ambitions of the Elector of Saxony and were part of his princely strategies for asserting control over his territory. However, this function of the instruments did not exclude that in some cases (or in the hands of some early modern users) they also served to make knowledge. In this paper we will argue for the role of the Dresden Kunstkammer in the creation of knowledge by focusing on a particular episode in the history of the collection, Johannes Kepler's visit(s) in the early 1600s. We will reconstruct the meaning of Kepler's encounter with the Kunstkammer by placing it in the context of the history of the Dresden collection itself and of the interest that the Dresden court had in Kepler and his optics (an interest which seemed to have been mutual). More specifically, we will argue that Kepler's witnessing of a camera obscura demonstration during his visit to the Dresden Kunstkammer was constitutive of his development of a theory of image formation, eventually published in his Paralipomena (1604). This specific episode is instructive for the role of Kunstkammern (and other early modern collections) in bringing contemporary material culture to the various branches of the domain of early modern mixed mathematics. Such an episode is also informative of the type of collection which was present in Dresden. Nonetheless, one should not lose sight of the larger courtly context of the collection, if one wishes to understand the acquisition of such scientific instruments as a group of early telescopes in 1613. In the last part of our paper we will highlight how subsequent curators (Michaelis and Walz in the eighteenth, but also Engelmann in the twentieth century) re-shuffled the optical instruments (and their parts) in Dresden -- sometimes physically, at other times on paper -- and re-used them for their own purposes. Such re-arrangements in fact drastically changed the meaning and status of the instruments.

**12 Dr. Peter Heering**
University of Oldenburg, Germany
**The Meaning of Practise**

The starting point of this paper is to discuss two instruments and the practice connected with these devices. In doing so, I am relying on practical experiences made in working with these

instruments - in one case an original one, in the other a reconstruction. Both devices were developed within some forty years, nevertheless, the practice with these instruments turned out to be completely different.
The first device is the solar microscope, an instrument that was created in the early 1740s and served to project microscopic images onto a screen in order to demonstrate them to an audience. Solar microscopes were very popular during the second half of the eighteenth century. However, during the nineteenth century microscopists discredited this device as being a mere toy but not a scientific instrument. This change in the notion of the device can be seen as a result of a different understanding of adequate scientific practice. Consequently instruments with different properties became icons of the newly developed concept - instruments that were no longer designed in order to be used in front of an audience. One of this iconic devices of the nineteenth century was the torsion balance developed by Coulomb in order to analyse electricity. In analysing the practice with this instrument and the context of its introduction as well as its transformation into an icon of science, the rejection of the solar microscope can also be explained.

**Location and Organisation:**

**Speakers are:**

**1 Professor Dr. Helge Kragh (keynote speaker)**
History of Science, University of Aarhus, Denmark
**The uses of scientific instruments in Denmark-Norway in the Romantic era**

**2 Dr. Allison Morrison-Low**
Science and Technology, National Museum of Scotland, Edingburgh, United Kingdom
**'It was a Dark and Stormy Night': Instrument Makers and the Northern Lights**
The lighthouses that have illuminated the nocturnal coasts of Europe since medieval times - except in time of war - enable mariners to find their way in safety through the darkness and past treacherous obstacles. The application of scientific principles to increase the strength of the illuminant and develop the optical apparatus, with particular reference to the case of Scotland, will be examined in this paper. It appears that the specific conditions of this environment meant that French and English expertise, as well as native Scots aptitude, were used to improve the effectiveness of Scottish sea-marking.

**3 Alexi Shannon Baker**
History of Science, University of Oxford, United Kingdom
**The London Instrument Trade, from Culpeper to Cole**

The London instrument trade grew rapidly during the late seventeenth century and stabilized during the ensuing decades, overshadowing instrument sale and production in the rest of Britain. Trade directories for the capital began to emphasize the financial gains and handsome shops that could be had from this 'very ingenious and profitable Business.' Several historians have investigated the craftsmen involved in this development, but there has been little broad analysis of the dynamics between instrument makers and sellers and the social, economic and geographical landscape of early eighteenth century London. I am exploring how these individuals reconciled the demands of dilettantes, professionals and experimentalists with their own need to make a living, as well as the nature of their relationships with related trades and with neighbors. Were their experiences significantly different from those of other early city-dwellers, or did their lives and businesses conform to common characteristics of urban life?
I am currently examining between 400 and 500 individuals who are known to have been at work within the instrument trade in London during the first half of the eighteenth century and also continue to discover people and details that were previously overlooked. The variability of early modern records is offset by the complementing of traditional sources and individual biographies with new resources and techniques, including computer-assisted mapping, digital data storage and analysis, and electronic indices and collections of contemporary material. These resources and techniques, which are increasingly employed within historical geography and early modern history, will assist me in the study of a variety of geographical and socioeconomic attributes over time to yield a broader and more dynamic understanding of the early eighteenth century instrument trade than has yet been achieved. My paper will present the trends that I have uncovered to date through textual, numerical and geographical analysis as well as questions that remain in the comprehension of the trade, its products and its

members.

**4 Drs. Tim Huisman**
Museum Boerhaave, Leiden, The Netherlands
**An Instrument of Encyclopaedic Knowledge in a Changing World. The Leiden Theatrum Aanatomicum 1592-1725**

**5 Alfonso Zarzoso**
Museu d'Historia de la Medicina Catalunya, Barcalona, Spain
**Instruments and Teaching of Surgery: New Educational Tools for a New School**

In late Eighteenth-Century Europe a number of institutions were created in order to instruct surgeons. Most of them laid foundations in such a didactic program that raised fears and competition on the part of physicians, still trained on the old university schemes. In the city of Barcelona, the creation of a Royal College of Surgeons in 1760 meant the introduction of novelties regarding the instruction program of surgeons. The architecture of the building erected for the training of surgeons indicates how some sciences started a process of consolidation and defined autonomy. Though the main place for the production of knowledge in that school was the anatomical theatre, considered as the true book of nature, there were room for the creation of ancillary places such as the library, a cabinet of anatomical specimens and a cabinet of instruments of "experimental physics". Each of these ambits was professionalized through the institution of specific posts and duties: librarian, curator and professor.
This contribution wants to look at these new places in order to assess how the shaping of a discipline was tied to specific educational tools. The analysis of the anatomical cabinet reveals how the school took profit from the material advances of the period to capture a moment of nature and participated in the exchange of knowledge through foreign acquisitions. This resulted in a clearly educational collection of a plethora of models or representations of natural objects in a range of media, especially wax. Even more important, however, was the method of ordering objects, a distinctive way of naming, dividing and classifying that permitted to attain a better instruction and a public utility. I will consider in similar terms the study of the cabinet of physics. The school of surgeons became another place in the city for the introduction of experimental physics. This will be revised in the light of the analysis of the instruments and machines of the cabinet. Again, the channels of acquisition show foreign purchase but also the emerging recruitment of local artisans as providers of specific copies of instruments.

**6 Dr. Erik Jorink**
Constantijn Huygens Instituut (KNAW)
**Dutch humanists and the microscope, 1620-1670**

**7 Dr. Lissa Roberts (keynote speaker)**
History of Science and Technology, Twente University, The Netherlands
**Running in Place: Location and Identity in the History of Dutch Steam Engines**

**8 Björn Brüsch**
Experimental Systems and Spaces of Knowledge, Max Planck Institute for the History of Science, Berlin, Germany
**The Technical Sphere of the Garden. Uses of Instruments and Garden Devises in 19th Century Gardening**

One of the most prominent images of a gardener using an instrument is probably the image presented in one of Humprey Repton's books. There, the depiction illustrates how a gardener is using a theodolite. While standing in an already gardenesque landscape that soon would be turned into a garden the person, standing in front of the surveying instrument, is probably an image least associated with every-day gardening practice. One would rather assume gardeners or people working in gardens depicted with a rake, scissors or a spade, all devices or instruments that share their existence with the actual doings of the gardener. Although one could assume that surveying techniques and the relevant instruments have been used quite regularly during the process of laying out a garden it nevertheless poses the problem of an adequate and widespread use. Looking at the school curriculum of the first gardener's school in Prussia, founded in 1823, it becomes clear that surveying was not a topic of choice. Gardeners, being educated at this school aiming for a specific and more prolific and scientific education of gardeners, did not have to go through a surveying course explaining the handling of both the instrument and the relevant theoretical background. Rather, the surveyor was to be educated within the realms of the Prussian Bauakademie at Berlin.

This nevertheless leaves the question to exactly why Repton and his contemporaries were using the above mentioned instrument while the institutionalized Prussian curriculum did not provide for it. Taking a closer look at the curriculum it becomes clear that instruments and the use of instruments and devices did not seem to play too much a role.

As there seems to be only little acknowledgement of the historical development of instruments and devices used within the practical sphere of the garden my presentation will try to highlight some aspects of both the usage and new developments of garden instruments. By focussing on the period of the early 19th century I want to argue that coming from a more or less strict handcraft background the instrument used within the gardens were part of a procedure coupled with an almost exclusive practical sphere. Accordingly both use and theory could only be taught by using the instruments and technical devices, as much as the material knowledge was also taught by the actual handling of plants. I further want to highlight some of the occurring changes which were due to the many technical developments of the time, and how new instruments and devices were successively incorporated into both practice and theory of garden art and gardening. This is emphasized by the gradually appearing text books of later decades in the 19th century - making garden art and gardening a much more scientific and technical enterprise.

**9 Dr. Christian Sichau**
Curator of Physics, Deutsches Museum, Germany
**Hidden Links: Early Attempts to Create a National Physics Laboratory in Victorian Britain**

Victorian Physics is a subject well explored by many historians from various perspectives. Nevertheless, a background theme shared by a number of important experiments by such

famous physicists like George Gabriel Stokes, James Joule, William Thomson or James Clerk Maxwell has not yet been examined in detail: The attempt to create a "national physics laboratory" at Kew. It was closely related to a controversial discussion in the 1850s about the relationship between science and the state. This debate between different groups of scientists can be seen as a re-definition what it meant to do science. In this paper I will sketch some important aspects of this development with a focus on the struggle to bring a "national physics laboratory" into live. Thus, I will add another - important - aspect uniting a specific group of scientists which played a central role in defining Victorian physics; a group which has been described to some extent by the historian of science, Crosbie Smith. In this history, instruments and instrument makers, personal friendships and (new) institutional settings, struggles about what it means to do science, theoretical physics and practical fieldwork in India, all these things and the many linkages between them suddenly emerge. In this paper I will elaborate this dense network.
Additionally, I will explore the possibility to tell a history of science as a biography of a physical entity, the "internal friction of fluids" - its emergence as a problem in the use of an instrument, its theoretical definition, its measurement with the help of a new instrument and its later "use" in the "field". This history which is part of the development mentioned above is based on a detailed examination of the instrument James Clerk Maxwell used to measure this physical quantity in 1865.
In summary, I will argue that the study of the history of scientific instruments / experiments can improve our understanding of some important developments of science in a particular period by highlighting some shared characteristics of various individual elements.

**10 Dr. Dirk van Delft**
NRC Handelsblad/Universiteit Leiden, The Netherlands
**'The Blue Boys': The School of Instrument Makers in the Leiden Physical Laboratory of Heike Kamerlingh Onnes**

Heike Kamerlingh Onnes (1853-1926) is famous for his work in low temperature physics. In 1882 Onnes started as a professor of experimental physics in Leiden. His scientific program was to test the molecular theories of his compatriot J.D. van der Waals. As a consequence he needed a laboratory for extremely low temperatures.
In 1908 Kamerlingh Onnes was the first one to liquefy Helium. Three years later he discovered the extraordinary effect of superconductivity. Such a Big Science effort couldn't do without strong technical support, and without precision instruments. The way Kamerlingh Onnes organized this support, by creating a school of instrument makers as an integral part of his laboratory, is a unique feature of his cryogenic work and a decisive factor in its success. Starting with one technician, Onnes soon opened the door of his (simple) workshop for a few 14-18 year old boys, who were trained as technicians. These 'blue boys' (the name refers to the work clothes they had to wear) were obliged to visit a local technical school in the evening. Onnes used this small army of cheap technicians (in 1898 there were 16 of them; six year later 32) for building up his laboratory and performing measurements.
To guarantee the continuation of the system, which was essential in running the huge cryogenic laboratory Kamerlingh Onnes needed, the workshop training was institutionalized. In
1901 the Leiden School of Instrument Makers was founded. It was completely integrated in the physical laboratory. The way Onnes succeeded to raise the money needed for this school and the way the school earned a solid reputation in Dutch technical education and abroad show that Kamerlingh Onnes was not only a very successful experimental physicist, but also a

brilliant organiser.

**11 Dr. Sebastien Soubiran**
Mission culture scientifique et technique, University Louis Pasteur of Strasbourg, France
**From Scientific Instruments to Technical Efficiency: British Royal Navy Technological Testing Process, 1913-1940**

My presentation aims to analyse the technological innovation process within the British Royal navy during the interwar period. More particularly, I will focus on how this military department, certainly the most powerful of the world at this time, developed a particular kind of gyrocompass to improve the accuracy of the fire control system of its ships during the interwar period. I will be interested in relating how this technical device became a scientific instrument. I would present the different group of people involved within the building process of this device, the different place, and the different tools and testing methods used to certify the technical efficiency of this instrument. The determination of the error and the methods of calibration should also be focused upon. What was the part of the error and of these methods in the construction of the technical object? How did each actor evaluate the error in their testing practices? What kind of instruments did they built and trust to evaluate this error? Thus, I would like to show how peculiar and specific this device was, related to the military environment it was built in and the specific needs this environment generated. Indeed, military department is genuinely interesting to understand the complexity of the negotiations involved in a scientific instrument building process, as the negotiation process seems to be incessantly on the move, the final step would be eventually war. One needs to adapt to a reality ("real" war) that one can only guess. The starting point would be the naval battle that should be translated into different methods of approximation, included numerous scientific instruments that I would describe. Each actor relies on specific criteria to define a context and tended to recreate artificially, with different experimental devices, this environment. The problem is precisely to make these different contexts link up. For instance, laboratories, workshops, docks and sea trials appeared to be the place where these technical representations were confronted and negotiated.

**12 Dr. Steindor J. Erlingsson**
Reykjavik, Iceland
**The Plymouth Laboratory of the Marine Biological Association and the Rise of Experimental Zoology in Britain**

The rise of experimental zoology in Britain was a slow process compared to the American story. Following Professor William Herdman's active promotion at the British Association meeting in 1895 of experimental zoology and promoting the necessity of a zoological station in Britain, where physiological work could be conducted, things moved slowly. It was not until the 1920s that Herdman's dream became a reality. The foundation of the Society of Experimental Biology (SEB) and the British Journal Experimental Biology (BJEB) by Julian Huxley (1887-1975), Lancelot Hogben (1895-1975) and Francis Crew (1886-1973) and their colleagues in 1923 were of key importance for the rise of experimental zoology, but the Plymouth laboratory of the Marine Biological Association of the United Kingdom was of no less importance. The Plymouth laboratory, founded in 1888, was the sole zoological station in Britain, but prior to the Great War it did not have facilities enabled proper physiological work. Hence, British zoologist needed to go to the Naples Zoological Station for such work. Due to

its German ownership the Naples Station was paralysed during and immediately following the war. Realising this, the Cambridge zoologists G. P. Bidder (1863-1954) was adamant that something needed to be done to further the possibilities for British zoologists to do experimental work. Bidder was a great benefactor of the Plymouth laboratory. As example he donated the funds that made possible the foundation of the laboratory's Ray Lankester Trust in 1912, which annually allocated a grant that enabled a zoologist to work at the laboratory for five months.

In 1919 Bidder set in motion a plan that aimed at building up a Physiological Department at the Plymouth Laboratory that became a reality in 1920 through private donations, mainly from Bidder, and a big grant from the Development Commission, which was established in 1909. Bidder was also instrumental in the further enlargement of the Physiological Department in 1924. The influence that the Plymouth Laboratory had, in conjunction with the SEB and the BJEB on the rise of experimental zoology is clearly seen in the fact that the percentage of visiting researchers doing physiological work rose from 6% in 1920 to between 40-50% in the period 1927-1930. These researchers came mainly for the universities in London, the University of Edinburgh and Cambridge University. Among the most important physiological work done in Plymouth in the early years of the Physiological Department was Edinburgh's Lancelot Hogben's pioneering work on the electrolytes in invertebrate muscle. He did this work in 1924 and 1925 as the Ray Lankester Investigator, which Bidder considered the "best thing that the Investigatorship had produced."

**Innovation:**

**Speakers are:**

**1 Dr. Filippo Camerota (keynote speaker)**
Vice Director and Collection Manager, Instituto e Museo di Storia della Scienza, Florence, Italy
**Admirabilis Circinus: The Spread and Improvement of Fabrizio Mordente's Compass**

Between 1567 and 1626 the compass of Fabrizio Mordente was the subject of growing interest among men of science in the most important courts of Europe. Its dissemination was due not only to Mordente's promotion but also, and more efficiently, to the writings and correspondence of renowned collectors, philosophers and mathematicians, such as Giacomo Contarini, Gian Vincenzo Pinelli, Giordano Bruno, Guidobaldo del Monte, Christopher Clavius and Michel Coignet. The instrument provided an innovative method for measuring the minimum fraction of a degree in order to determine longitude at sea. Its history is an exemplary case of the development and spread of ideas in Renaissance Europe. Beyond the official route of printing, the channels through which this compass was disseminated are to be found in the correspondence between scientists, in the earliest scientific collections, in public demonstrations for the purpose of sales, and in contacts between simple amateurs. Even the perfecting of the instrument was the work of others. Some modifications were made by Rudolph II, who suggested that a further point should be added; by Michel Coignet, who modified the proportional rule to be used with the compass, and by some unknown instrument makers who made changes now visible on the extant specimens but not to be found in the literary documents.

**2 Dr. Yaakov Zik**
Department of Philosophy, University of Haifa, Israel
**Theory and Practice of Early Telescopic Observation: Galileo and the Telescope**

Theories of physical science need an interface between symbolic representations and the real world. Observations, experiments, and the technological means that facilitate them provide such interface. Galileo Galilei's telescopic enterprise of which he first wrote in 1610 in his Sidereus Nuncius offers an illuminating example of this interface between theory and instrument.
A pivotal event in the course of modern science, the introduction of the telescope poses a fundamental question to the historiography and philosophy of scientific change: how are we to understand an instrument as an object that encapsulates knowledge which is not of propositional nature?
The very invention of an instrument exerts a relation between symbols and the theories within which it is employed. For Galileo it was clear that in order to measure and interpret natural phenomena correctly he needed to develop an appropriate method which makes use of instrumentation. It is thus instructive to regard the scientific instrument at the heart of Galileo's enterprise-the telescope-in this light and examine the linkage Galileo established among theory, method and instrument.

**3 Pedro Raposo**
Astronomical Observatory of Lisbon/Center for the History of Science of the University of Lisbon, Portugal
**Down-to-Earth Solutions for Celestial Purposes:**
**Remarks on the Life and Works of the Astronomer/Instrument Maker**
**Campos Rodrigues (1836-1919)**

In 1869, César Augusto de Campos Rodrigues (1836-1919) joined the staff of the Astronomical Observatory of Lisbon, during the instalment of its main instruments. The international expectation over this new Observatory was high, because it was meant to be the most occidental node in the network of European observatories committed to the development of sidereal astronomy. But, after generous endowments that allowed a promising foundation, support from the national authorities started to fade.
As a young military engineer, Rodrigues was already renowned for his hydrographical surveys and his ability to develop practical devices and techniques, which fitted very well the needs of the fieldwork. He was also a reputed Navy Officer who had revealed a strong sense of duty and readiness to find quick responses and solutions, in face of such situations as the imprisonment of pirates and ship wreckage. Once at the Observatory, his commitment to duty, together with a confessed passion for astronomy, led him to carefully study and improve almost every instrument available there. He also designed original and useful devices, as well as graphic calculation techniques and tools. Combining the practical sense developed in the fieldworks with the accuracy patterns of astrometry, these equipments allowed him and his few fellow astronomers to produce high-quality astronomical work. Such accomplishments led him to be awarded the Valz prize of the Academy of Sciences of Paris, in 1904. Allegedly too humble to publish descriptions of his devices, he was, nevertheless, always willing to offer his services and advice in instrumentation and related issues. Thus, fellow scientists and technical personnel from other institutions consulted him very frequently, and many devices were ordered and manufactured at instrument workshops according to his instructions. The need to establish and improve time and meteorological services throughout the Portuguese overseas empire was the source of many of these requests.
This approach to the life and works of Campos Rodrigues aims at understanding how individual skills and values, life experience and the broader context in which a scientific institution is embedded, converge with specific needs of the scientific work to produce a versatile scientist/instrument maker.

**4 Dr. Suzanne Débarbat**
Observatoire de Paris, France
**From Sea to Land: from Hadley’s octant to Danjon’s astrolabe**

Hadley's octant, following one of Newton's idea, was designed around 1730. It was soon employed by Halley, Bouguer, Maupertuis and others, mostly navigators from Great Britain and the Low Countries. Being later designed as a sextant, it was used, not only at sea, but also on the ground by Gauss for surveying. Several new instruments appeared by the end of the XIXth century for similar purposes. Among them two, the prismatic astrolabe and the circumzenithal, have been in use for almost one century, under various designs, for time, polar motion determination and land surveying.

**5 Nicolàs de Hilster**
Independent scholar, The Netherlands

**Reconstruction of the ‘spiegelboog’**

**6 Dr. James Caplan**
Observatoire de Marseille, France
**The Least-squares Procedure and Astronomical Instrument Development in the 19th Century.**

At the beginning of the 19th century the repeating circle, first small and then larger, enjoyed considerable prestige for astronomical observations, although there were lingering doubts about its accuracy. But the last decades of the previous century had seen the development of large circles to replace the problematic quadrants, and by the 1830's large meridian circles were the standard instruments of observatories, as the repeating circle faded away. Improvements followed quickly, and by 1870 the meridian circle had essentially reached its final form. These developments were taking place at the same time as major innovations in the reduction of astronomical observations, particularly the use of least squares. Were these instrumental developments and reduction innovations related?

**7 Marc Ratcliff (keynote speaker)**
Institut d’histoire de la médicine et de la sauté, Université de Genève, Swizerland
**From Users to Makers : Using, Improving and Conceiving Microscopes During the Eighteenth Century**

**8 Dr. Marian Fournier**
Museum Boerhaave, Leiden, The Netherlands
**From the Laboratory to the Factory: Le Poole and the Electron Microscope**

**9 Jérôme Fatet**
Laboratoire Interdisciplinaire de reserche en Didactique et en Histoire des Sciences et Techniques, Université Claude Bernard, Lyon, France
**How New Instruments Come to Be**

The invention of photography came about as a progress in the domain of technology, but the scientific community was very quickly interested in it. First used in his initial function, producing pictures, its procedures are little by little adapted to the needs of research. The scientist Edmond Becquerel (1820-1891) was eighteen years old in 1839 when the principles of photography were published in France. He took immediately interest in this development. As photographer, he produced pictures of Paris, but as physician he uses the chemical principle of this new technology for his research in physics.
In this communication we analyse this transfer of methods from the technical community to the scientific community, and in particular the construction by Edmond Becquerel of a device known as the electrochemical actinometer, using the chemical principles of photography, but without producing pictures, for the analysis of the solar spectrum. With this instrument, Edmond Becquerel obtains results that he claims prove that the rays "beyond purple" are light. Our exploration of the origins of this instrument is based, first, on the analysis of the description, in different communications to the French "Académie des Sciences", of three

devices, built by Edmond Becquerel, which lead him to the invention of the electrochemical actinometer. Second, we use information we collected during the replications we did of these different instruments.
We observe how this instrument was invented, constructed, and transformed by Edmond Becquerel between 1839 and 1843. We also analyse which parameters influenced this evolution. We particularly explore the influence of a controversy caused by this invention, between Edmond Becquerel and the famous French physicist Jean-Baptiste Biot. This controversy seems to be essentially based on experimental dissension. But Biot is known for his unfailing defence of the corpuscular theory of light. This point drives us to analyze if any theoretical influences concerning light motivated Becquerel's work, and if so, which one. Finally we examine the impact of these scientific developments on the domain of technology by analysing how this instrument is modified and used by photographers, such as the development of one of the first sensitometers.

**10 Prof. Richard Kremer**
History Department, Dartmouth College, Hanover, NH, USA
**Inventing and Marketing a New Stroboscope: Harold 'Doc' Edgerton and the General Radio Company from 1932-1960**

In December 1932, the General Radio Company of Cambridge, Massachusetts (one of the USA's first 'electronics' companies, founded in 1915) announced the availability of its first optical instrument, the Type 548-A Edgerton Stroboscope. Patented by the recently appointed MIT assistant professor, Harold E. Edgerton, and produced by General Radio, the 548-A would be the first in a succession of stroboscopes to be developed by a continuing collaboration between the instrument company and members of MIT's department of electrical engineering. By drawing on patent records, Edgerton's laboratory notebooks, and General Radio's extensive trade literature, this paper will explore the nature of the collaboration. Edgerton's unpaid research assistants, Herbert Grier and Kenneth Germeshausen, built new cameras and flash tubes, respectively. Edgerton made the famous stroboscopic flash photographs that boosted public awareness of the new technology. And General Radio and its MIT-trained engineers built robust, portable devices that they marketed to a host of industrial, medical and educational users. By examining the technical changes in the General Radio strobes from 1932 to 1960, the paper will also consider how various users' demands shaped the evolution of the instrument (the 1960 version remains available in an essentially unchanged form despite the disappearance of GenRad in 2001).

**11 Charles Care**
Department of Computer Science, University of Warwick, Coventry, United Kingdom
**From Instrument to Computer: The Development of analogue computing**

The users of analogue computing employed techniques that have important similarities to the ways scientific instruments have been used historically. Analogue computing was for many years an alternative to digital computing, and historians often frame the emergence of analogue computing as a development from various mathematical instruments. These instruments employed analogies to create artefacts that embodied some aspect of theory. Ever since the phrase 'analogue computing' was first used in the 1940s, a central example of analogue technology has been the planimeter, a nineteenth century scientific instrument for area calculation. The planimeter mechanism developed from that of the single instrument to become a component of much larger and more complex instruments designed by Kelvin in the

1870s and Vannevar Bush in the 1920s. Later definitions of computing would refer to algorithms and numerical calculation, but for Bush emphasis was placed on the cognitive support provided by the machine. He understood his "differential analyser" to be an instrument that provided a "suggestive auxiliary to precise reasoning" and under the label "instrumental analysis", classified all apparatus that "aid[ed] the mind" of the mathematician. Rather than placing emphasis on automation, an analogue computer provided an environment where the human investigator was far more involved in the computation process.

This paper will argue that the analogue computer can successfully be considered as a scientific instrument. The role of the analogue computer as a scientific instrument will be investigated from the perspective of the users' techniques and applications. The study will particularly focus on the users' approach to the planimeter, the differential analyser and the electronic analogue computer.