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The Potsdam System in the 20th Century: Rise and Fall of a Centre of Gravity

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Introduction

This session is devoted to spatial aspects of the nexus between science and technology. I will argue that spatial perspectives can be enriching or even essential to the understanding of scientific practices in what is today called the earth sciences. A case study of a global system of gravity measurements offers a good example of how strongly systematic knowledge production in this field rested on a combination of local and trans-/international spatial arrangements or: of place and space. The result was far from being a seamless web of interactions, but rather a monocentric form of knowledge production, called the “Potsdam Schweresystem”. This system rested – so the argument - on (1) a strong social and techno-scientific microstructure, (2) its relational stabilization with continuious field measurements and data-collections, and (3) its organizational consolidation in a network of transnational and international dimensions.

On the other hand, a multi-layered spatial arrangement that rooted in micro-places and encompassed various scales “up” to the global strongly depended on the spatial order of the nation-states and their alliances; an order that underwent dramatic ruptures in the 20th century, ruptures, that – so the thesis - step by step destroyed the knowledge space of the “Potsdam system”: In the course of the 20th century, as I will argue, it declined due to the gradual interruption of the flows of knowledge, data and artefacts that constituted the various spatial arrangements. It was finally replaced by a new, spatially decentralised and technologically pluralistic regime in 1971.

Spatiality and Knowledge Production in the Earth Sciences

Since the 1970s "earth sciences" has become the all-embracing term for sciences related to planet earth, encompassing physical, chemical, mathematical, geological and other subfields. Neither earth sciences in the 20th century nor its various disciplines have attracted much interest from science historians or STS.[1] I would like to give some introductory remarks that concern some of the epistemological particularities. This is because these features are very important to the understanding of the crucial role that spatiality played in their history and their current practice. The sociological and historical research on "epistemological cultures" and "epistemological practices" raised the awareness of the varying relations between scientists, their instruments, their objects, their working places etc. These are mostly exemplified in case studies on laboratory work.

In contrast to this predominant spatial form of 20th century science the earth sciences strongly depend on observing and measuring practices in the field, i.e. in the physical and natural places where the phenomena under study occur, be they the oceans, or, in my case, the surface of the earth. Earth scientists measure, collect and process data about physical, chemical and geological features over large spaces (in fact the whole planet[2]) and over large periods of time. Nevertheless this cannot be described as a pure "field science" because the geographically extensive and technologically demanding observations depend on a combination of laboratory and field work, of experiment and observation, of collecting and processing practices. Above all, the continuous, large-scale and often border-crossing flow of data has to be organised on a long-term basis. From the 19th century on, the earth sciences had strong international and transnational components. Scientists began to organise knowledge production in multilateral projects spanning territorial borders. As projects mostly depended on a combination of technical expertise, scientific excellence and resources to process large amounts of data from near and faraway places, they often developed strong centres, the nodal points in centralized networks. These were exactly the kinds of places that Bruno Latour once called "Centres of Calculation." One of these centres and one large-scale system of knowledge production connected to it are described in this article.

[1] With the emergence of climate change this situation has changed dramatically, but disciplines with minor contributions to climate studies are still largely neglected.
[2] This dependence on physical presence weakened from the 1970s on, when remote sensing and satellite technology gained prominence.

The Potsdam system of gravity measurements

The starting point of my studies is a single location of knowledge production, namely the so-called Telegrafenberg. This is a research site located in Potsdam, near Berlin, that was build in the 1870s and 1880s. The site was carefully chosen by a commission because it had an excellent train line to Berlin and optimum conditions free of disturbances for astrophysical, geomagnetic, meteorological and other observations. Immense sums were spent on buildings designed specifically for the research activities they housed. One institute located here since 1892, the "Geodätische Institut," became the centre of a global measurement system for earth's gravity in the early years of the 20th century. This system was soon known and internationally accepted under the name "Potsdamer System." From 1909 to 1971 it was the globally accepted referential system for gravity measurements, i.e. all measurements were related to an absolute value of gravity measured on the Telegrafenberg in Potsdam, where other national and regional centres of measurement made "connecting measurements" ("Anschlussmessungen") with Potsdam.[3]

At the apex of the technological and scientific system was an absolute measurement of the period of a pendulum developed in the Institute. This required systematic investigation of all possible influences on the measurement, including temperature, air pressure, relative humidity, materials and friction. Pendulums had to be tested and improved, and time measurement had to be brought to a new precision. In 1892, one of the most advanced science buildings of the era was finished to bring together all required technical skills and knowledge. And finally, in the eight years between 1898 and 1906 systematic experiments and measurements were carried out (mostly by Friedrich Kühen and Philipp Furtwängler and - only rarely mentioned - for the important time measurements B.Wanach), resulting in the "Potsdam value of gravity."[4] The difficulty lay less in the complexity of the individual instruments and more in the ensemble and the fine tuning. This required manual and technical skills and arts, knowledge of materials and a spirit of invention. The laboratory work inspired the technicians, whose efforts produced better scientific results – a science-technology nexus that comprised knowledge flows in both directions. The success of the measurements depended on a dense local network of instruments, advanced laboratory buildings and excellent scientific practices, its social foundation was a network of scientists, instrument

[3] This required the physical presence of foreign scientists and their instruments in Potsdam.
[4] Bestimmung der absoluten Größe der Schwerkraft zu Potsdam mit Reversionspendeln von F. Kühen und Ph. Furtwängler, Berlin 1906.

makers, calculators, architects and government officials concentrated in the area of Potsdam and Berlin.

But to convert a single example of scientific and technological excellence into a “system” of global dimensions required much more than laboratory work. Nobody knew better than the leading “architect” of the system, Friedrich Robert Helmert (1843-1917), the director of the Geodetic Institute from 1885 to 1917. From the beginning of his administration the Geodetic Institute started to systematically collect data on relative gravity measurements from all over the world.[5] A data base encompassing measurements from 1808 onward was systematically converted and referred to the new absolute measurement, making the Geodetic Institute the single most important holder of coherent gravity data in the world. Data collections from important national and international measurement series were connected to the Potsdam value.[6]

To build the local network and its scientific results, to build the growing data collection and processing activities into the foundation of an international measurement system: this finally required the use of another Potsdam-centred network, by then already operating, that of its excellent connections to scientists, institutions and officials in the leading nations. This network of transnational and international dimensions rested on the fact that the Geodätische Institut in Potsdam acted as the “Permanent Bureau of the Internationale Erdmessung”, an international project in geodesy with around 25 contributing nations at the time. The project was successful during the heyday of internationalism in science in the second half of the 19th century. The “Geodätische Institut” used its position to implement the gravity system: Helmert and his colleagues presented their work on pendulums, precision measurements in their laboratory, field measurements, data collections etc. to scientists from 24 nations at the 16th General Conference of the Internationale Erdmessung in London in 1909.[7] After a short discussion it was agreed to make the new value of the Potsdam measurement the fundamental value of a new system, soon to be called the “Potsdam System.” A new global system of gravity measurements was established, resting on a strong local fundament in the Berlin-Potsdam area and on numerous border-crossing linkages that connected the system to

[5] 1898 ca. 1300, 1900 ca. 1600 gravimetric points.
[6] In 1900 the Geodetic Institute had processed data from 14 main stations, in 1909 already from 20, most of them located in Europe.
[7] E. Borrass: Bericht über die relativen Messungen der Schwerkraft mit Pendelapparaten in der Zeit von 1808 bis 1909 und über ihre Darstellung im Potsdamer Schweresystem, in: Verhandlungen der vom 21. September bis 29. September 1909 in London und Cambridge abgehaltenen Sechzehnten Allgemeinen Conferenz der Internationalen Erdmessung, Berlin 1911 III.Theil S.1-288.

measurements all over the planet and enabled a continuous flow of data, persons and artefacts. As so, knowledge production on gravity from then on was organised in a very distinct spatial order: local resources had been concentrated in a unique arrangement on the Telegrafenberg. But more than that, the arrangement was established as a hub in a border-crossing space of knowledge production that had a centripetal character, orientated towards its “centre of gravity” (in a double sense): Potsdam.

But only a few years after its initiation, the complex arrangement of the Potsdam system formed its first cracks: The first World War and the following decades revealed its fragility, as from 1914 on political and territorial ruptures repeatedly changed its framework.

1914-1945: Local and transnational spaces collapsing

When World War I broke out, the system of border-crossing collaboration in the earth sciences came to sudden end. The whole project of “Internationale Erdmessung” and Potsdam’s position as its “Centralbureau” were abandoned. A new structure of international collaboration emerged in the early 1920s, explicitly excluding Germany and its wartime allies for a few short but formative years. The Potsdam System survived in part because the value of the Potsdam absolute measurement was accepted by the successor of the “Internationale Erdmessung,” the “International Union of Geodesy and Geophysics (IUGG).” But the crisis in the international space of the system slowed down its cumulative stabilization: The number of transnational “Anschlußmessungen” from other important gravity stations declined significantly after World War I and sank even further with the advent of the Nazi government in Germany and the outbreak of World War II. Potsdam scientists then participated in an aggressive policy of data collection in the occupied countries. They were part of large relative measurement campaigns, the gravimetrical part of the oil exploration programme for the German war economy.

The crisis in obtaining transnational data reflected the development of Potsdam’s “official foreign relations:” After the crisis in the years after 1918, the Germans collectively boycotted international conferences in the Western hemisphere from 1925 on, a nationalistic position that continued until the mid-1930s. New contacts to eastern Europe could not compensate for the lost relationships to the rest of the world. Just after the situation improved in 1937, Germany started WWII and its scientists fell into even deeper isolation.

The ongoing weakening of its international position – that also brought financial losses - induced ruptures in the local foundation of the system. Potsdam could not hold its leading position within the Prussian and German science system; the highly productive network with instrument makers began to dissolve, the Potsdam Institutes weren’t able to stimulate significant demand. The stagnation and centrifugal tendencies weakening the authority of the Potsdam system, retarded efforts to improve on the initial absolute measurement.
The effect was that the Potsdam measurement was openly challenged in the 1930s and 1940s. It was found inaccurate in measurements by two major authorities: the US Bureau of Standards in Washington (1936) and at the British National Physics Laboratory in Teddington (1939).[8]

Postwar Decades

For the microstructure of persons, laboratories and instruments in Potsdam the situation at the end of WW II was staggering: military units from East and West swarmed to confiscate instruments and data; many of the surviving staff left for western Germany. After Potsdam became part of the Soviet Zone (and later East Germany), the Soviets took away part of the equipment. The situation was worsened due to divisions and fragmentations in the geographic and territorial order. The spatial position of Potsdam changed drastically: Not only was Germany divided into four occupation zones and later two nations, but Potsdam was cut off from its local and regional network, from old connections to universities and government departments now situated in West Berlin, but also from its instrument makers, for example the by then leading “Askania Werke.”

The odds that the authority of the Potsdam Absolute Measurement could be renewed were limited by staggering constraints. New measurements that deviated from the Potsdam value were made at the “Bureau des Poids et Mesures in Sevres” near Paris in 1952 and Leningrad in 1956.[9] As data on gravity became essential for missile guidance, on both sides of the Iron Curtain substantial resources were invested in geophysical research und measurement projects. A generation of new instruments, gravimeters, was developed to a level that reached the accuracy of precision pendulums, a development on which Potsdam missed out on for a long time.

[8] B. C. Browne, E. C. Bullard**: Comparison of the Acceleration due to Gravity at the National Laboratory, Teddington and the Bureau of Standards, Washington, D.C.** , in: *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences*, Vol. 175, No. 960 (Mar. 28, 1940), pp. 110-117.

[9] E. Rieckmann/S.German: Das Potsdamer Schwersystem, seine vollständige Definition und seine richtige Übertragung, München 1957.

In Potsdam the scientists were not able to react. A new measurement was constantly delayed because of missing components in the instrumentation required. They were missing due to the territorial and political economy of Cold War Europe. Not only had the old technological networks of the Berlin/Potsdam area collapsed, but the small East German state was not able to provide all the special instruments required by industry and academic research institutes. Due to the political map of the Cold War, the importing of precision instruments needed in Potsdam was almost impossible; the situation worsened even further in 1961 when the Berlin Wall abruptly put an end to the special economical relationship with the western part of Germany.

In addition to the instrumental and scientific crisis of the system, the cumulative and transnational character of the system was collapsing. The number of so-called Anschlußmessungen that required the physical presence of scientific teams from other countries at the Geodetic Institute declined dramatically, falling even under the number during the 1930s and 1940s. The Potsdam scientists were not able to improve the situation with activities in the international science organisations. The "foreign relations" of German science were drawn into the foreign affairs conflicts of the two German states. East German scientists were refused full admittance by international organisations because no agreement on the representation of the two German states was reached until the early 1970s.

In spite of all constraints, the Potsdam scientists were working and spending major resources on all levels to re-stabilize their system. The costs for repairing or renewing the technological basis – now requiring interferometers and atomic clocks - were enormous. When possible, hard currency was spent to import instruments, especially from West Germany. Otherwise instruments were built within the laboratories themselves or within specialised institutes of the Academy of Sciences. Potsdam scientists struggled for representation within international science organisations in the 1950s and 1960s; from 1957 on, following the "International Geophysical Year", they began to build closer ties to neighbouring countries to the east, trying to reinstate the authority of Potsdam on at least a regional and transitional basis.

This could not stop the ongoing decline. In major international meetings of the IUGG in the 1950s and 1960s the Potsdam value was found to be inaccurate.[10] When the system was finally replaced by what was called the "The International Gravity Standardization Net 1971," not only had Potsdam lost its position as the node of the system, but the whole arrangement was changed to a decentralized und multi-instrumental mode. The concept differed from that of the earlier gravity reference systems in that its result is not determined by a collectively adopted value measured at one single station. Instead the result is determined from the gravity values from no less than 1854 stations using a single least squares adjustment of absolute pendulum and gravimeter data. A decentralised system based on two technologies was established. The new system - called ISGN 71 – obviously fit into the more complex scientific, territorial and institutional landscape of the second half of the 20th century. Geophysical knowledge now was produced in a expanded landscape of military, government and science institutions. The geographical distribution was far more widely distributed than fifty years earlier; now major actors were in Asia and Latin America. In the late 1960s the number of member states in the leading international organisations of the earth sciences reached 100, four times as many as during the "Internationale Gradmessung" before World War I. Besides, no system with a centre located in one of the rivalling Cold War blocs was capable of winning a majority in the international organisations.

When the Potsdam scientists finally succeeded in producing a new absolute measurement with pendulums in 1970, it was too late: its value became a regional point of reference for the socialist countries. Globally, a whole new spatial regime of knowledge production had been established; the old system rooted in 19th and early 20th century science with its concentrated single science centres had come to an end. The science and technology of gravity measurements now was distributed widely across the planet (but not everywhere and not equally). With regard to Potsdam and the Potsdam System we can identify processes of delocalisation and decentralisation of knowledge production, but it has to be pointed out that this was not a general trend in the earth sciences as a whole. A good example is the rise of remote sensing and satellite technologies from the 1960s on: Again, a highly concentrated process was dominated for quite some time by a few space science centres located in only a few superpowers.

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[10] Sigmar German: Das Potsdamer Schweresystem. Seine Geschichte bei den internationalen Organisationen, München 1961.

The gradual decline of Potsdam was also accompanied by the rise of new centres, i.e. new processes of localization. As so, we are confronted with developments that in spatial perspective took quite differing paths. If we want to propose a more general thesis about the spatiality of the "science-technology dyad" in the 20^{th} century, we can (1) observe the important role of locality and co-presence in the emergence of technology-intensive research practices such as gravity measurements. With the diffusion and enhancement of such practices the centres tend to lose their positions and new (sub)centres emerge. This is far from being a linear process, because (2) changes in the spatial order of knowledge production strongly depend on the structure of and developments in the territorial order. The history of the Potsdam system with its local, regional, national and international ruptures in the course of the 20th century, with its strong dependence on the measurements all over the planet, may not be a representative example, but it is one that can raise the awareness for the role of spatial configurations that bring persons, artefacts and knowledge, that bring science and technology into cooperation.

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