11. Follow the Films. Reuses of a Research Film: Biography, Recycling, Whitewashing, Appropriation and Palimpsesting

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Introduction

In 2009, the city of Göttingen installed a plaque commemorating the achievements of the engineer and physicist Ludwig Prandtl. For a town that promotes itself as a "city that creates knowledge," it is—in times of tourist marketing—an obvious means to tag the city map with the biographies of important scientists. More noteworthy is that at the same time, the daily newspaper *Göttinger Tageblatt* published a DVD with two films that Prandtl made between 1927 and 1933. Scientists' biographies abound (there is also a good one about Prandtl, Eckert 2017), but the 'life' and 'afterlife' of scientific films has so far been largely unexplored. As this article will elaborate, it was neither the first nor the last reuse of this particular film, nor are the manifold reuses of (scientific) films a singular case. We believe that it is key for the understanding of scientific films to follow their reuses, their circulations, their recyclings, their appropriations and their trajectories, or in short and based on the methodological catchphrase of the Actor-Network-Theory (ANT): to *follow the films!* (Latour 2005, 12, 237)[1]

Until recently, scientific films have escaped the attention of academic research. Film studies were, until 20 years ago, almost exclusively interested in feature films or art films (Hediger 2005). In Science Studies, it was often only mentioned in a side note that scientists had also produced and worked with cinematography or more recently with video. Although there is extensive literature on the role of the visual in the sciences (Hentschel 2014), the vast history of scientific filmmaking is still mostly unknown. The existing studies focus primarily on films from biology (Landecker 2006; Schultz-Figueroa 2018) and medical sciences (Cartwright 1995; Schmidt 2002; Olszynko-Gryn and Ellis 2017) and are devoted almost exclusively to the period before the First World War (Canales 2009; Curtis 2015). The role of films in popularizing science (Boon 2008; Gaycken 2015), in teaching (Alexander 2010;

Orgeron, Orgeron, and Streible 2012), or in sex education (Laukötter 2019) has also been considered.

Despite these relevant studies over the past 20 years, there is still a striking lack of literature on the following questions: How were scientific films produced in the laboratory, but also and even more so, how, why and when did they leave the laboratory, and if so, how were they distributed, instrumentalized, handled and reused outside the laboratory (Hediger 2005; Zimmermann 2011)? How did they eventually become part of teaching films, science communication films, experimental art films, feature films, etc.? And also, how have scientific films been archived (Ziehe and Nägele 2013)? Answering these questions and developing an understanding of the function of films in the sciences might help to clarify basic (mis)understandings on the side of the scientists working with film and on the side of the audiences confronted with film as instruction, evidence or truth.

In order to approach the history of scientific films, we suggest following them from the first attempts at their production and evaluation to their repeated reuse in different scientific disciplines and broader contexts in order to better understand the multiple and subtle intertwinements between science, politics and the public sphere. By pointing out the range of variations that the same material can cycle throughout history, our aim is to better map the aesthetic, intermedial and cultural transformations associated with the constant 'reuse' and 'recycling practices' of film material. We want to show that scientific films cannot be fully understood at just one point in their existence but rather through their processes and ongoing analog as well as digital (re)cyclings (Sattelmacher, Schulze, and Waltenspül 2021).

In the interest of clarity and brevity, we will focus on only one example: a flow film called *Entstehung von Wirbeln bei Wasserströmungen* (Production of Vortices by Bodies Travelling in Water) by Prandtl and his doctoral students Oskar Tietjens and W. Müller, which focuses on basic research questions in fluid dynamics (Fig. 11.1). This film has had an eventful history spanning almost 100 years. It serves us to discuss the ways in which films circulate through space and time—in their changing materiality (from 35 mm nitro film to 16 mm safety film to different file formats) and visuality (from a rough cut to reedited found footage to digitally color-graded and noise-reduced) as well as their shifting epistemic functions (between measurement, research, teaching and popularization).

To approach knowledge circulations through this scientific film, we will draw, on the one hand, upon the literature about the circulation of things and their entanglement with knowledge (Bauche and Vogel 2016; Gugerli et al. 2011; etc.) while considering, on the other hand, the medium specificity of film; since film is not only a material object (as film reels, strips or celluloid) but also and foremost, a moving image when screened. Film is also tied to editing and narrativization. We will start our story of Prandtl's flow film with the idea of transferring the "object biography" to research film, because it is one of the most prominent concepts to

describe shifts of identity, value, meaning or materiality that occur when things are moving through time and space. By pointing out the strengths and weaknesses of the biography approach, namely its anthropomorphic connotations and the linear path of development it implies, we afterwards suggest writing the further history of the film by its constant reuses through different institutions and persons. As has been thematized in the literature on art films, a wide array of recycling practices has been constitutive in the history of film (Blümlinger 2009; Jutz 2010). We are going to show that procedures between experimental montage, found footage appropriation and format transfers are common, not only in contemporary video art but throughout the history of scientific film. In a close reading of the film's history we suggest expanding that repertoire of possible reusages of film material even more.

Film Biography: From the Laboratory into the World

Ludwig Prandtl experimented with film since 1912 (Prandtl 1912/1961, 1267). Especially after the early 1920s, he and his doctoral students spent a lot of energy trying to extract measurements from celluloid. They even redesigned their amateur cinematograph to create a hybrid between photo and film camera (Schulze and Waltenspül 2019). If we were interested in the progress of theories and measurement technology, we would have to reason that by and large Prandtl's experiments with film failed. But following the trajectories of Prandtl's "cinematographic desires" (Canales 2011, 330) allows for a different narrative. After years of experimenting, he changed his strategy and produced a film for demonstration purposes, namely for one special event: The Wilbur Wright Memorial Lecture held at the Royal Aeronautical Society in London in 1927 (Fig. 11.1a) (Prandtl 1927a/1961, 1545; Prandtl 1927b/1961). The lecture and the associated prize were a big success. This was proof that Prandtl's theories were recognized abroad (after their long rejection, Bloor 2011) and that he had become the most acknowledged flow researcher of that time (Eckert 2017, 164–169). For Prandtl, the film was a welcome means of visually illustrating, conveying and underpinning the central ideas of his boundary layer theory and therefore the successes of his career—especially given his poor knowledge of English at the time. Just like people who surround themselves with personal things to develop their personality and reflect on it, Prandtl used the film as part of a narrative process of self-defining his career.

Although the idea that not only persons but also 'inanimate' objects might have a life to be told can be traced throughout Western and particularly Non-Western cultural history, the idea is usually credited to social anthropologists Arjun Appadurai and Igor Kopytoff claiming that the (de)commodification processes of things can be viewed biographically (Appadurai 1986; Kopytoff 1986).

Figure 11.1: Different verisons of the Göttingen flow film from 1927 to 2009

Subsequently, the concept was expanded to other media and to knowledge circulation: e.g. scientific images (Hagner, Mazzolini, and Pogliano 2009), data (Peled 2014, 107), scientific concepts (Daston 2000), cities (Arnold 2002) or media events (Lash and Lury 2007). As far as we know, the only application of the concept to film comes from the theologian Dwight Friesen (2018), who analyzed how biblical films function in the daily lives of Christians.

One central idea of Kopytoff, who coined the term "biography of things," and his followers is that the life cycle of a thing is often tied to the biography of a per-

son (Kopytoff 1986). Tracing the transfers of ownership, i.e. who is allowed to have it, to borrow it or to use it, and tracing its journey from production to its loss or disposal is a way to gain insights into the lives, status or living conditions of the people linked to the thing. The insight that the histories of things and the histories of people are difficult to separate can also be applied to scientific films and our example: indeed, Ludwig Prandtl and the film he produced became intertwined. Following Kopytoff by asking questions similar to those one would ask about people, it becomes not only evident that a scientific film can assume different functions and meanings but also—following later adoptions of the object biography concept (Hoskins 2006)—that this particular film had an effect on the biography of its maker(s). Adopting the perspective of an object biography leads to central questions: Where does the film come from? Who made it, under what conditions and for what purpose? What has its 'career' been afterwards, and what did its makers consider as its ideal 'career'? How did it travel through time and space?

Prandtl was known mainly for his airfoil theory and his boundary layer theory, which he developed in a seminal paper in 1904/05 (Prandtl 1905). However, he never managed to find a general mathematical description of the boundary layer separation behind cylinders and other pivotal objects in aerodynamics, like airfoils or bluff bodies. Therefore, he used film as a way of showing and demonstrating the vortices caused by boundary layer separation. That is remarkable, given the fact that visualizations often had a precarious role in fluid dynamics, and that they were usually subordinated to mathematical descriptions (Bloor 2008). But following up on his lecture in London, Prandtl began to frame the film increasingly as a kind of visual evidence. He even used it as an argument in written discussions. In 1928, he wrote in a response to his opponent Friedrich Ahlborn, with whom he was in a dispute about the theory *and* about the film itself: "For what follows now, there is no actual theory, but a qualitative doctrine proven by the visual material but not explainable by the exact language of the formula"[2] (Ahlborn 1928, 184). As a consequence of the mathematically insolvable vortex formation, visuality seemed to have gained relevance over numbers.

If the medium of film had disappointed Prandtl's hopes two years earlier, the film he finally produced became part of his theory, at least to a certain extent. This underlines what Lisa Cartwright raised in response to the concerns expressed by Bruno Latour, Ian Hacking or Michael Lynch about the visual in Science Studies, namely that the visual may often be a dead end, and it may have misled scientists time and again, but from this it cannot be concluded that the visual is valued too highly: "To dismiss the visual as overrated is to overlook the role of pleasure as an important factor in scientific process" (Cartwright 2014, 251). Using the notion of biography in the context of scientific films can provide new perspectives and questions about how scientists are involved with the visual material they produce and distribute. Film biographies, therefore, might help in the shifts from studying

the life of the (white male) scientist, through his papers and theories, to studying the scientist's practices of conveying, of creating credibility and providing authority to the reception of his work.

As visual evidence, the film began to travel: in 1929, Prandtl took it along on his around-the-world trip and showed it at several research institutes in Moscow, Tokyo, Kobe, Stanford, Pasadena, Urbana Il, Ann Arbor MI, Detroit, Pittsburgh, Washington DC and Boston.[3] Prandtl's trip was also a kind of 'tour' adding to his fame and his theories. On this tour, the film was always with him—at least until it was stolen on the platform of Detroit train station. But even if colleagues reassured him that his lectures would be very interesting even without the film, Prandtl secured a new copy of it from his former assistant Tietjens, with whom he had made the film and who was at that point—what a coincidence—employed in Pittsburgh. In other words, the film not only took part in consolidating Prandtl's influence on the emerging field of fluid dynamics, it had also become an indispensable companion for Prandtl. Prandtl himself seems to have become a "showman," as Tom Gunning called exhibitors of early films and film shows, attracting the audience by the act of showing moving images and supplementing them with other show elements (Gunning 1997).

The early history of Prandtl's film shows that the concept of the object biography can also help understanding the circulation and transfer of scientific knowledge through film. Congruent to the insights that Samuel Alberti highlighted with regard to object biographies, film biographies can offer a "narrative hook" for telling the history of knowledge circulation, they can embed the study of scientific practice in visual culture, and they can be "a prism through which to view various publics' experience of science" (Alberti 2005, 560). Furthermore, by bringing the scientists' individual desires and biographical path dependencies into focus, they can help us to understand the often-implicit conditions of the circulation of scientific ideas—especially when we read the biography of the film together with the biography of its beholder.

However, the application of the notion of biography to objects has been criticized (Hahn 2015) and it also needs to be scrutinized in relation to film. Mainly, two points of criticism are pivotal: anthropomorphism and linearity. Firstly, the forms of existence of material objects and also of film reels contradict the laws of life cycles. There is no birth and death, emergence and transience, no clear definition of beginning and end. What would a rediscovered film copy—like *Metropolis* in 2008—be: a zombie? In order to avoid this critique, the terms "trajectory" (Rheinberger 2000) and "itinerary" (Hahn and Weis 2013) have been proposed. But they do not escape the second point of criticism, which regards the linear and singular path of development that a biography and, even more so, a trajectory insinuates. The film can be replaced by another copy. Although one material film reel is anchored like its owner in a particular space and time, the film can be everywhere

and nowhere due to its reproducibility. Furthermore, as a reproducible object, the film is not used up as are most everyday commodities (such as food, clothing, etc.). Scientific films in particular are often entities in-between material objects and endlessly reproduced visuals. Often, they exist as only one or a few copies. And as the first episode in the history of the Göttingen flow film shows, they can assume a kind of unity with their owners as long as they stay close to them, and they can be formative for their owners' identity. Therefore, the biography concept should not be given up too hastily but rather be critically examined and expanded. Because when it comes to the circulation of films beyond the scientist's sphere of influence, there might be other useful approaches that do not fall into the traps of implying one singular path in circulation and of anthropomorphizing the film. In order to write the history of this film and broaden the concept of object biography, we suggest looking at the specific and often singular practices of reusing the film: recycling, whitewashing, appropriating, remembrance and palimpsesting.

Recycling: Raw Materials for Nazification

The subsequent history of the film shows how the biography of the film and the biography of its author started to diverge. In the 1930s, the film entered the Reich Office for Teaching Films (*Reichsstelle für den Unterrichtsfilm*, RfdU, later called Reich Institute for Film and Images in Science and the Classroom, *Reichsanstalt für Film und Bild in Wissenschaft und Unterricht*, RWU), founded in 1934 as a branch of the Reich Ministry of Science, Education and Culture (*Reichsministerium für Wissenschaft, Erziehung und Volksbildung*, REM), which aimed to unite and standardize the education system in Nazi Germany. As the film theorist Yvonne Zimmermann states "[b]y removing useful films from their original context, they . . . are placed in a new addressing context" (2011, 133).[4] This change of the addressing context was not only accompanied by a change in the function of the film—from a research and lecture film to an instructive and educational film—but also to an increase of the numbers of its copies and its radius of distribution. Because of this, the previously suggested concept of biography is no longer suitable for interpreting these episodes and needs to be expanded. By framing this episode as a recycling, in the sense that is used in today's everyday language, we hope to emphasize the economic and political relevance of films in circulation beyond their original context. 'Recycling' is discussed virulently in the literature on circular economy (i.e. Sillanpää and Nicibi 2019), as opposed to a linear economy with its take, make, dispose strategy, discarding material that is still valuable. Within a circular economy, recycling describes the process of converting waste into something new by breaking it down into raw materials.

The following episode is about the history of Prandtl's flow film in the 1930s: How did it find its way into the distribution system of the RfdU, how was it massively reproduced? How was it commodified in what was perhaps the first and biggest educational program mainly based on film as its pivotal medium: the National Socialist Gleichschaltung?

Even though the idea of using film as an educational tool is much older than the National Socialist ideal of *Gleichschaltung*, a project on the scale of the RfdU only became possible by overcoming financial, organizational and technical difficulties first (Tolle 1961, 10–17). With the introduction of the so-called contribution to learning resources (*Lernmittelbeitrag*) and of 16 mm acetate safety film instead of the easily inflammable and toxic nitrocellulose film, the basis for forcible coordination was set. And, as stated in the founding decree of the RfdU, film, being one of the "most relevant aid[s] in teaching," could be "put at the service" of the National Socialist "worldview" (Rust 1934, 24).

In 1935, the unification of the German education system was expanded to include research and teaching in higher education. The new university department (*Hochschulabteilung*) was financed by students with 1 Reichsmark (R.M.) per semester, the same amount as the learning aid contribution *Lernmittelbeitrag* for school children.[5] The department contacted Prandtl that same year. By pointing to the "common goal" of serving German research and the education of young scientists, they asked him that "this working copy, which contains individual negative sequences in random order, should be cut and transformed into a meaningful version. As far as possible, this version should already meet the requirements of university teaching."[6] Prandtl himself put in great efforts to do so. He changed the intertitles, the sequences and their order; he cut the film, with a seemingly satisfying result.[7] The RfdU called the form of the title and the repetition of the sequences "exceptionally valuable from the standpoint of teaching methods."[8]

In 1936, the RfdU finally published the film in two parts as "C1" and "C2" with an accompanying text by Prandtl (Fig. 11.1b). C stands for university film (*Hochschulfilm*) and the number one signifies that Prandtl's film was the first in the media catalogue and rental system of the university department at the RfdU (RfdU 1936, 24). The fact that they were nationally and internationally famous is reflected by the number of ordered copies.[9] Thus, in cooperation with the RfdU, Prandtl transformed the research film that he showed at conferences (with a primary epistemic function) into an educational film for technical universities (with an instructive function).

In the case of C1, a film from a research context was recycled to become an educational film. Although this reuse implies a certain predictability, this episode shows likewise that the "trajectories" of the film are not as clearly foreseeable as the ballistic term trajectories implies. Prandtl's version of the flow film was not only shown at conferences by its creator, and the recycled RfdU version was not only

multiplied and shown in lecture halls. Its entrance into the distribution system and the increasing commodification of the film also allowed its parallel and multiplied uses in new contexts: the film became an object of political negotiations and of military interests.

Remarkably, in 1936, the history of the film C1 and the history of the later Institute for the Scientific Film (IWF Göttingen) crossed for the first time: Gotthard Wolf, an employee of the RfdU, contacted Prandtl. Wolf later founded the IWF and the Encyclopedia Cinematographica, and therefore became a key figure in the field of scientific films in Germany and beyond. Before the war, Wolf asked for Prandtl's advice concerning "basic clarification" about the delivery of films to "private institutions." He mentioned an order of C1 by the Heinkel aircraft manufacturing company, which was the biggest producer of airplanes in the first half of the 20th century and which worked for the German Army Ordnance Office (*Heereswaffenamt*) after 1935. Wolf also writes that orders had accumulated in the past and even though a decree by the Minister of REM, Bernhard Rust, only permitted the delivery to universities and their institutes, he was counting on Prandtl's opinion. Prandtl replied that he was not requesting a special arrangement, but that he wanted to be informed of the Minister's decisions. The special decree to deliver the RfdU films to ministerial and half-ministerial institutions as well followed shortly after.[10] It could therefore be concluded that not only the contexts shaped the film, but that the film might also have formed such contexts as the RfdU. Basic research on fluid dynamics—like the visualization of the boundary layer theory in Prandtl's film—provided valuable information for aerodynamic applications and these were definitely not restricted to classrooms.

This episode from the 1930s provides at least two insights for a better understanding of the movements of scientific films. The first is related to the medium specificity of film: Due to the opportunity to change the material structure of a film, to recut and revise it, a recycling of previously existing material for new purposes becomes feasible. For a National Socialist institution such as the RfdU, this even made it possible to recycle—or from their standpoint even upcycle and valorize—the film for the intended unification of the education system in Nazi Germany. The second insight is rather time specific: It was not until the 1930s that an institution of the scale and range of the RfdU became operable. Even though Prandtl had already made a few copies of the film reel himself (using them as a gift or taking them along on his world tour for screenings), the high numbers of copies and especially their distribution on a large scale only became possible through 16 mm safety film and the specialized structure of the RfdU. This in turn led to a new mobility of scientific films. The increased numbers of copies could be used in new contexts such as military defense, for instance. Therefore, the movement of scientific films cannot only be grasped with linear concepts like biography or trajectory. Reuse practices like recycling, on the other hand, would do justice to both

the medium specificity and the mobility of films. Or what might be described with the words of Balsom as "circulatory reproducibility," as the ability to copy or reproduce film, therefore "transforming that singular trace into something multiple that is primed for circulation" (Balsom 2018, 5).

Whitewashing Films and Tarnished Institutions

Although the history of this scientific film is not a linear one, its institutional history from the pre- to the postwar period was in many respects rather continuous and trajectable: The usage of the film has basically not changed, as the educational function also remained central in the postwar institution. But to reuse a film which was widely screened in Nazi Germany in directly war-related contexts meant that there were crucial changes necessary on an ideological level: the film as well as the institution needed to be whitewashed from their brown past.

In 1952, the history of C1 and the history of the later IWF intersect for the second time: Gotthard Wolf, now the head of the so-called university and research department of the Institute for Film and Image in Science and Education (*Institut für Film und Bild in Wissenschaft und Unterricht*, FWU) contacted Prandtl again, thanking him for the delivery of the original negatives of the films C1 and C2. Wolf writes that without his help a reconstruction of the film would not have been possible. Furthermore, he mentions that the film is still one of the "most requested films ever."[11] Remarkably, Wolf wrote this letter from Bunsenstraße 10 in Göttingen to Prandtl in Bunsenstraße 10 in Göttingen. After the war, the former buildings of Prandtl's Aerodynamic Research Institute and the Kaiser Wilhelm Institute for Flow Research had to host many of the newly founded institutes of the Kaiser Wilhelm respectively the Max Planck Society, parts of the general administration as well as the IWF (Henning and Kazemi 2016, 38–39).[12] Hence, Bunsenstraße 10 was among the centers of the (re)organization of German cutting-edge research. This must have also shaped Wolf's perspective and his aim to create an internationally recognized institution. To do so, he needed to whitewash the film collection of the RWU, for which "the archives had absolutely to be replenished" again.[13] Thus, Wolf put in great effort to collect either the original material (i.e. from authors like Prandtl) or copies of burned, destroyed or lost films from the *Landesbildstellen* and other institutes. Wolf used both legal and illegal strategies to do so. One rather harmless strategy is described by the historian Ulf Schmidt in his outstanding research on the history of medical research and teaching films from the RfdU/RWU: "In order to gain control over scientific films, Wolf borrowed high-school films from the IfdU [*Institut für den Unterrichtsfilm*] in Munich, but never returned them" (2002, 280).

Besides this restocking of the film collection, the institution and the films also needed to be reorganized on an ideological level in order to be reused. Or to express this in the words of Captain Gregory Buckland-Smith, member of the British Control Commission of Germany and the person responsible for the first comprehensive postwar report on the RWU: "purged of all Nazi and militaristic material," the organization could be reestablished (quoted from Schmidt 2002, 276). The films as well as the institution needed to be denazified—at least *prima facie*. Representatives from the British and American occupying powers viewed, classified and regulated the resumption of the films in distribution. Almost all the films from the university department passed the censorship of the U.S. Office for Military Government for Germany. They only forbade about 15 films out of more than 400, and some others needed to be cut.[14] Nonetheless, the films still needed to be denazified. This process included the replacement of the RWU logo and in some films emblems like swastikas needed to be cut out. Regarding the two films C1 and C2—now heading the media catalogue of the IWF—only the RWU logo was replaced (Fig. 11.1c). Over and above that, the content remained the same.[15]

Besides these official and legal strategies of denazification recommended by the allied powers, Wolf also pursued unofficial strategies in order not to 'lose' too many films: In a letter to the director of the FWU, he suggests replacing the names of biased film authors with the name of their institutes. Among others, this concerns the name of Paul Rostock, former chief of the Office for Medical Science and Research. He was at that time inter alia accused of human experimentation within the Nuremberg doctors' trial. Wolf furthermore recommends not speaking about his suggestion with Buckland-Smith immediately:

> The question is particularly complicated because there is probably a considerable number of films that were made by professors who are no longer in office due to their political views. It would be an extraordinary loss if all these films could not be used in the classroom anymore. Therefore, in individual cases, it may be necessary to only mention the name of the institute from which they originate instead of the name of the person responsible.[16]

By all available means, Wolf was trying to find ways, on the one hand, to seemingly denazify the collection, and on the other hand, to continue to distribute the films from the RWU notwithstanding the issues involved. To reuse the films, one could say, one further strategy to make this continuity acceptable was to whitewash the RWU politically. Schmidt mentioned how not only former RWU and later IWF employees depicted the RWU as a "center of tolerance" and a "political oasis" during the war, but also how this view was reproduced by later historians such as Michael Kühn (1998) and Malte Ewert (1997) (Schmidt 2002, 129–134; see also Kuhlbrodt 1998).

The successful whitewashing of the films as well as the institution was one of the necessary conditions for the reuse of C1 and other films in the IWF, for the reuse of films in the Federal Republic of Germany produced in times of National Socialism and for the goal of *Gleichschaltung*. This underlines again that films cannot be viewed isolated from their cultural, social, institutional and political contexts. Even if films remain mostly unchanged, as in this case (except for the institutional logo), they might be reused in a completely different political environment. Knowing and analyzing these different contexts and environments is therefore absolutely crucial to an understanding of the unpredictable and incalculable reuses of (scientific) films.

As this episode shows, the whitewashing of scientific films does not even need any changes of the content. This says a lot about the deep-rooted assumptions that scientific images are allegedly objective, unpolitical and unideological. The history of Prandtl's laboratory film bears witness to the fact that this may not be the case. Even if brown tinges can be whitewashed, they may still circulate latently with the films and migrate from reuse to reuse.

Appropriating Found Footage of a Flow Film for US Science Education

The overall structure and appearance of Prandtl's research film stayed largely intact in all its previously mentioned reuses, in spite of all the revisions and refunctionalizations by the RfdU, the RWU and the IWF. Similar to an object reused in a different context, the labels were changed and there were recuts, rearrangements, improvements, damages and small material losses here and there. The following episode of another reuse breaks with any directly recognizable correspondence to the original film: only very few snippets were reused in this case and appropriated to assemble a new product on celluloid.

In the early 1960s, scenes of only a few seconds from Prandtl's recordings appear in the US Science Education Film *The Fluid Dynamics of Drag* (1960) and later in the films *Vorticity* (Fig. 11.1d) and *Flow Visualization*. These films were made at the MIT and became part of an introductory course in fluid dynamics for college students produced by the National Committee for Fluid Mechanics Films (NCFMF). In addition to 39 sound films, the NCFMF later published 133 silent films of a length of 2 to 4 minutes in the Super 8 film format. Seven of them consist entirely of scenes from Prandtl's footage (Shapiro 1972, 172, 182, 207–209).

Ascher Shapiro was head of the program and author of the films mentioned. It is not clear from where Shapiro got the footage. In any case, no correspondence between him and Prandtl has survived. What can be deduced from the image sections and the scenes he reused, especially in the 8 mm films, however, is that Shapiro had 35 mm film material from Prandtl's laboratories available and not only a 16 mm copy

from the IWF of an overall lower quality with cut edges. He may even have had material at hand that Prandtl had left during his world tour. Inquiries of MIT students from the 1930s at Prandtl's Göttingen Institute prove at least that the film had been part of the curriculum long before the foundation of the IWF.[17]

In the history of film, there is an abundance of examples for repurposing film material in new works, usually categorized as found footage films. Especially in avant-garde film since the 1930s, footage of all kinds has been used to craft an entirely different visual experience through editing (Wees 1993; Blümlinger 2009; Jutz 2010). This type of reuse is hardly comparable to the reuse of material objects or still images. While it is quite possible that only individual parts of everyday objects are reused—think of spare parts inventories—, this usually goes hand in hand with the loss of their identifiability. When recycling something (e.g. printed paper) it is often even necessary to erase the previous meaning of the object (e.g. the document). In (analog) film, on the other hand, the reference to the original film is often retained, and in many cases this reference is even foregrounded. The film remains attributable: a link between the reused film and the original film remains recognizable.[18] When you know Prandtl's films, it is easy to identify the snippets from them in Shapiro's college education films. It is important to emphasize this possibility of reuse, which seems specific to film, because it goes along with a different mobility of the film images. The found footage appropriation contributes to the fact that scientific films can overcome spatial, temporal and political boundaries—in some cases surprisingly easily. This happens despite the fact that analog film at least appears to be far less mobile than other scientific inscriptions (compared to the printed image or text, films are expensive, chunky and inflexible in reception or analysis, etc.). In other words, found footage appropriation allows increased mobility as well as increased recontextualization, while keeping a certain immutability of the inscription.[19]

The border-crossing abilities of scientific films (in this case science education films) can also be exemplified by Shapiro's reuse. His films were part of a much bigger educational scheme: Beginning in the mid 1950s, and most notably after the Soviet Union successfully released Sputnik I in 1957, the US Government massively increased the funding of the National Science Foundation in order to improve the teaching and communication of science. A year after Sputnik, the National Defense Education Act was passed, several hundreds of million dollars were directed towards improving American science curricula. New textbooks, source books, classroom equipment and films were developed. The period from the 1950s to the 1970s was the peak phase of educational film production in the US, with more than 10,000 films a year (Orgeron, Orgeron, and Streible 2012, 52). In particular, educational programs in physics played a pioneering role (Rudolph 2012). The science education hype associated with the Sputnik crisis served three main purposes of the US government. First, the new curricula were intended to motivate more students to study

science in order to cushion the sweeping shortage of scientifically trained personnel. Secondly, the courses were supposed to supply the country with personnel who could support the military with scientific means. After all, the extremely successful and almost mythically charged large-scale research initiatives of the Second World War had shown how closely scientific research was linked to any military superiority. And third, the curricula were part of a cultural-psychological war over the power to define research and science. Particularly the discipline of physics stood for rationality, freedom of ideology and freedom of research. While the Soviet Union was waging a struggle against "bourgeois science," science in the West was regarded as an apolitical undertaking. The paradox, however, was that it was precisely this seemingly "unpolitical" science that was a cultural weapon with which the US government wanted to counter totalitarian regimes and lead the world to democracy (Wolfe 2018). As part of this cultural war, science education films were distributed globally, dubbed in several languages or offered for appropriation in other school systems—with funds from the US government and intelligence agencies, among others. As a result, Shapiro's films with the snippets from the Göttingen flow films were also distributed worldwide. They are still in use today and are available on several video-sharing platforms. Some reach click counts in the six-figure range.

Shapiro's appropriation of parts of Prandtl's film demonstrates that scientific films can bridge geographical, chronological and political rifts in an especially smooth manner when used as found footage. A mere reuse of the National Socialist university teaching film C1 for US science education would hardly have been conceivable outside the small community of specialists in fluid dynamics. However, the use as found footage does not imply that it was employed only accidentally as an *objet trouvé*, or as orphan film. The reuse was rather programmatic: Shapiro's first film is one of the very, very few of the physics education films that show research film material that is neither closely connected to the experimental apparatuses featured in the films nor produced in the US. But particularly the publications accompanying the film emphasize that the connection between the two films is not just to be found in some snippets. Shapiro published a book that he describes as "the film in print." In the preface he states: "I am indebted . . . to the late Ludwig Prandtl for classic film sequences now thirty years old as well as the inspiration of his style . . ." (Shapiro 1961, xv). And even its cover cites the Prandtl movie (Fig. 11.2). Shapiro roots his educational film project for the Space Race and the cultural war with the Soviets in the tradition of Prandtl. Hence, at least elements from Prandtl's film served as a main ingredient for educational films not only in 1930s Germany but also in 1960s US science education.

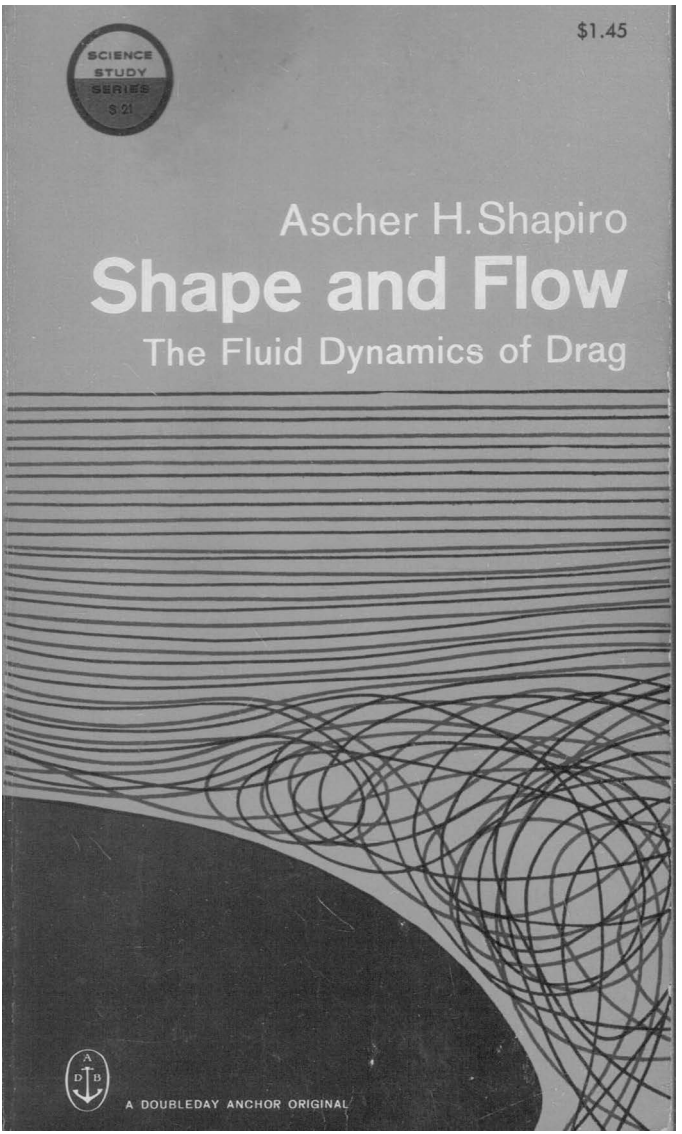

Figure 11.2: Book cover of *Shape and Flow*, which cites a scene from Prandtl's movie.

Remembrance: The Film as Historical Testimony

In the penultimate episode, we return to the plaque installed in commemoration of Ludwig Prandtl in Göttingen in 2009. As mentioned at the beginning, the *Göttinger*

Tageblatt, in cooperation with the IWF, published a DVD with Prandtl's flow film on the occasion of this event (Fig. 11.1e). In the course of commemorating Prandtl's successes and his reputation, the film was treated as if it were an object of remembrance: "Old Films New on DVD" and "Historical Films of Vortices and Currents" headlined the articles in the *Göttinger Tageblatt*, and the IWF press release talks about the "nostalgic appeal" of the "authentic" research recordings as well as their "clarity and validity" (IWF 2009).

The former laboratory film, then educational film, then archive film, thus became a memorial film, analogous to the objects of remembrance in museums or, more generally, in public spaces that recall the great and small achievements of the dead. The term memorial film does not signify a film whose content is memory or remembrance, but a film that is a historical testimony in itself and to which collective or individual memory can be attached (Erll and Wodianka 2008). As such, the flow film served a double commemoration. On the one hand, Prandtl, the "father of aerodynamics," was remembered. Thereby, the film illustrated Prandtl's field of research, his ideas and his ability to bring together the image and mathematical theory of flow (Broelmann 2001, 16). Thus, it also represented the glorious past of Göttingen science at the beginning of the 20th century. On the other hand, the film release commemorated the institution that had distributed the film (and many others) internationally for over 70 years. After all, the IWF was already at a late stage in its decline at that time. A little over a year after the DVD was released, the IWF was finally liquidated.

This episode stands for yet another kind of reuse typical for objects that mediate between the individual and society. The film was transformed into a means of collective memory and thus served different political intentions of the past. It was now tourism marketing for the "city that creates knowledge," a memorial to a figurehead of aerodynamics and a monument to a dying institution, which was once of great international importance for scientific film. Much could be said and questioned about the function and category of memorial film. To what extent did the film serve an individual, social, collective or political memory? To what extent can scientific films, which are characterized by the assertion that they depict something timeless, independent of place and time—which is particularly true of the physical disciplines—be functionalized as bearers of memory?

These questions cannot be answered here. What is decisive at this point, however, is that a perspective on the reuse of scientific films raises precisely these questions and makes them addressable. This underscores the fact that the imperative *follow the films!* not only provides insights into the historicity of the medium and its subject, but also exposes a kaleidoscope of historically different public approaches to the sciences.

In recourse to the concept of object biographies already presented, one could speak here of a rapprochement between the biographies of the film and its author

after years of separation. In commemoration, the object finds its way back to its original owner Ludwig Prandtl. The biography of the film is a co-biography of its creator in his 'afterlife' as well. But the film does not end up as a memorial object. Rather, at this point it takes an unforeseeable turn and its story continues.

In regard to this subsequent as well as to the previous reuse as a commemorative film, a mediatechnical *a priori* was crucial: The recordings, once produced on 35 mm material and then distributed on 16 mm, had to be digitized, MPEG2-encoded and stored on DVD. The reformatting (Rothöhler 2018) of the analog material meant, on the one hand, a massive loss of quality (image resolution in Pal standard)—which in the rhetoric of the circular economy can be described as 'downcycling.' On the other hand, the transition to another format and its digital publication enabled new uses for the film.

Palimpsesting: Reentry in the Research Context

Paradoxically, the release of the film on DVD, which for the first time in the film's history was aimed at a larger nonscientific or nonschool public, led to a reentry into its original scientific discipline: fluid dynamics. As there was an image plane added to the film, this reuse can be specified with the practice of palimpsesting, an early cultural recycling technique, which is characterized by the layering of different pictorial/temporal planes.

Jürgen Kompenhans, head of the experimental methods department at the German Aerospace Center, was among the readers of the *Göttinger Tageblatt*. Prandtl and his research were well known to him. He immediately ordered several DVDs of Prandtl's films and analyzed them with his colleague Christian Willert using particle image velocimetry (PIV). PIV is an algorithm-based optical analysis method for flows, which has evolved since the 1980s and is now one of the standard methods in fluid dynamic research. Kompenhans himself played a decisive role in its development. However, Willert and Kompenhans did not publish the data obtained from their PIV analysis, but in turn produced a film entitled *PIV Analysis of Ludwig Prandtl's Historic Flow Visualization Films* (Fig. 11.1f; Willert and Kompenhans 2010). Similar to Prandtl, Willert and Kompenhans showed their PIV film at conferences. In June 2010, they received the Best Movie Award at the 14th International Symposium on Flow Visualization in Daegu, South Korea. 80 years after the creation of the flow film, its reformatting and rerelease on DVD thus led to a reentry into its original research context, which had changed in terms of the technological possibilities for quantifying and dating the phenomena.

What does this film show and in what way is it a palimpsest? The film visualizes data obtained by a numerical analysis of the digitized historical film material. Colorful areas and streaks can be seen behind black objects on a grey background

with white dots. If one reads the film images together with the scale in the lower right corner, it becomes clear that the colored as well as the white areas provide information on vorticity, which describes the rotation of fluids around their own axis and is a central parameter in meteorology and fluid mechanics. What is decisive at this point is that the original film shines through the colored areas as a black-and-white background. The superimposition of colorful visualized data and translucent black-and-white film corresponds in its visual appearance to a palimpsest. Originally, palimpsests were used to designate texts that were removed from their material carrier by scraping or washing, so that the document could be reused for new texts. The deeper layers remained more or less visible, which could lead to correlations of meaning. Palimpsests with their different layers of meaning have been prominently theorized in literature, postcolonial theory (Osthues 2017) and image studies (Krüger 2007). As a "cultural technique of early recycling," palimpsesting enabled valuable material to be reused and recodified or even eradicated (Krüger 2007, 140).

Willert and Kompenhans' reuse of the film is essentially characterized by an intervention into the layers of the film image and differs in this respect from the practices discussed so far. The layering of current data visualization and historical flow visualization also enables new forms of knowledge. The layered image thus makes the historical circulation of knowledge images visible. Willert and Kompenhans not only turned Prandtl's research film into a data film (Adelmann et al. 2009), but also traced the PIV method back to its historical origins. In the film palimpsest, the historically superimposed layers are quasi reconciled. From a science-historical perspective, one could say that Willert and Kompenhans argue with images about images, with films about films. In doing so, they demonstrate what is still considered a desideratum in both the text-heavy humanities and the data-driven natural sciences: the acknowledgment of (scientific) images and films in their historical, material and aesthetic multilayeredness as visual arguments.

Conclusion

The "object biography" is probably the most prominent concept that lends itself to following the circulations, trajectories or better, reappearances of scientific inscriptions after their production in the laboratory. By providing a narrative hook for a longer historical time span and at the same time allowing for case-based analysis of situated practices, a film biography, modeled on an object biography, also delivers valuable ideas to better understand the multiple and subtle forms of intertwinement between science, politics and the public sphere. Nonetheless, we have argued in our article that, especially in view of the media specificity of film (as a reproducible, material and visual 'object' that is realized when screened), the biog-

raphy-approach needs to be adapted to describe the circulation of knowledge and power through scientific film. Hence, it is a matter of how to obtain the advantages of the concept without falling into its traps of implying a singular path or even anthropomorphic life cycles of films. Therefore, we suggest generally expanding our repertoire of investigating film migrations and relocations by focusing on the often-contingent reuses and reappearances of a film throughout history. A conceptual toolbox for describing single reuses is needed, so that not just *the* one but all or most of the itineraries of a scientific film can be followed and retraced. Fields like circular economy, for instance, which seem at first glance to have little to do with film and knowledge circulation, as well as closer fields, like the literature on found footage art films, can serve as rich conceptual, methodological and practical sources. In this toolbox, object biographies, trajectories and circulations should be supplemented by film reuses from up- or downcycling to whitewashing, to found footage appropriation, to reediting for remembrance, to palimpsests, and maybe more.

Prandtl's film is assuredly one of the most remarkable examples of a scientific film. Prandtl produced a research film hoping to take measurements in the 1920s. What he got was a film that secured the legacy of his visualizations not only in Nazi Germany and in West Germany, but also during the Cold War period in the US and in the present Flow Vis community. In order to discuss concepts of film reuse, this article has caught some glimpses of this film's even broader history. Above all, there is a need for further discussion on why especially this film has traveled so well through time and space and is still in use today. In short, there is a wide array of reasons for its long journey, beginning with the influence and fame of its maker Prandtl and the special significance of the subject it deals with. After all, in the last 100 years the acceleration of movement through air and water became one of the central goals for military as well as civil technological development. From this perspective, it is not surprising that a film promising to provide a key to understanding these movements has had a particularly successful career. Nonetheless, there are other reasons why this film in particular survived long after its first examination in the laboratory: its "immediate clarity" (Wise 1995, 231), its aesthetics, its hypnotic character, the pleasure it provides, but also the specific and complex history of the film itself. After all, the routes of circulation the film took created path dependencies that secured the next reuses of the film. For example, without its prominent position in the media catalogue of the RfdU/RWU and later the IWF, it would never have been PIV-analyzed 80 years after its production.

To conclude, in the last 50 years, studies in the history of science, technology and media have embraced a focus on practices of knowledge production and circulation. Along with that, master narratives of ingenious men and inventions were questioned, which have long dominated the field and which scarcely leave room for friction and fractions. Following scientific films can add to these critical ap-

proaches and help to fill a gap in the increasing literature on the visual practices of science (Beaulieu 2014; Galison 2014). Instead of emphasizing ideas, theories or experimental settings of scientific knowledge production, a focus on the reuses of scientific films—understood as correlating the production, distribution, reformatting, archiving, reception and other forms of reusage with one another—supplements historical epistemology with the possibilities of a political and economic epistemology of the visual.

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Notes

1 This research was funded by the Swiss National Science Foundation (Grant 173038). We would like to thank Anja Sattelmacher very much for her valuable contributions in terms of initiative, concept and discussion related to this article.

2 "Für das, was nun weiter erfolgt, ist also keine eigentliche Theorie mehr vorhanden, sondern nur eine an dem Anschauungsmaterial geprüfte qualitative Lehre, die nicht mehr in der exakten Sprache der Formeln ausgedrückt werden kann."

3 On this and the following details about Prandtl's trip around the world, cf. the correspondence in the Archive of the Max-Planck-Gesellschaft (AMPG III/61/1984; AMPG III/61/1985) and the "Bericht über eine Studienreise durch Amerika" in the Central Archive of the German Aerospace Center (GOAR 3663). In the following, all archival materials will be referenced in endnotes.

4 "Durch die Herauslösung aus ihrem ursprünglichen Kontext werden Gebrauchsfilme . . . in einen neuen Adressierungszusammenhang gestellt."

5 Bernhard Rust, Runderlass 06.02.1935 (AMPG I/44/1305).

6 "Diese Arbeitskopie, die in wahlloser Folge einzelne Negativabschnitte enthält, ist auf eine sinngemässe Fassung zu schneiden und zu kleben. Diese Fassung müsste möglichst schon den Anforderungen des Hochschulunterrichts gerecht werden." Dautert/Schwarz to Prandtl, 1935 (AMPG I/44/1305).

7 See the correspondence of Prandtl and the RfdU, 1935–37 (AMPG I/44/1305; AMPG I/44/1306).

8 Von Werner/Schwarz to Prandtl, 1935 (AMPG I/44/1305).

9 See "List of the 50 most requested university films" (Liste der 50 meistgefordertsten [sic] Hochschulfilme), n.y., probably around 1948 (TIB IWF 12485).

10 Correspondence of Wolf/RfdU and Prandtl, 1936 (AMPG I/44/1306).

11 ". . . noch immer zu den meistgefragtesten Unterrichtsfilmen überhaupt . . ." Wolf to Prandtl, 1952 (AMPG III/61/739).

12 The history of the RWU's subsequent institutions in the time after 1945 and before the official foundation of the IWF in 1956 is complex, but important for an understanding of the history of scientific films in Germany: in September 1945, the former university department and the special department for technical research film (*Sonderreferat technischer Forschungsfilm*) of the RWU already received a work permit as the department of technical research film (*Abteilung*

technischer Forschungsfilm) under the direction of Wolf in Höckelheim. At the end of 1945, the Institute for Film and Image (*Institut für Film und Bild*, IBF) was founded in Hamburg (but also active in Hanover) belonging to the British zone. Schmidt points out that many of the former RWU personnel "affiliated with the regime, made their way into the British zone" most probably due to the more modest program of denazification there (2002, 279–280). Furthermore, if the Allies wanted to quickly reestablish the organization, they rather needed to softly vet the RWU personnel (282). In 1946, the Institute for Educational Film (*Institut für den Unterrichtsfilm*, IfdU) was founded in the American zone and was based in Munich. The IfdU and IFB "were competing for financial resources, film equipment, raw film material, negatives and film copies of the former RWU stock" (275). As a result of the union of the three Western zones into the Trizone, and the increasing doubts "over the character of the Hamburg institute" (281), both institutes merged in the Institute for Film and Image in Science and Education (*Institut für Film und Bild in Wissenschaft und Unterricht*, FWU), based in Munich in the US sector. Wolf's Höckelheimer Group became the university department of the trizonal FWU, and it was moved to Göttingen in 1949, directly on the site of Prandtl's Aerodynamic Research Institute, into the removed wind tunnel at Bunsenstraße 10 (Ewert 1998, 233–234; Kühn 1998, 235–238; Schmidt 2002, 275–284).

13 ". . . dass wir unbedingt unsere Archive wieder auffüllen müssen." Correspondence of the Göttinger university department with the FWU concerning orders of copies, 1951, see also the correspondence with the *Landesbildstellen* (TIB IWF 16083).

14 Correspondence Wolf (at that time *Institut für Film und Bild in Wissenschaft und Unterricht* in Höckelheim) with Krämer from the Munich institute (at that time *Institut für den Unterrichtsfilm*, IfdU), 1948 (TIB IWF 16083); see also in-house correspondence in the Göttingen institute, 1950 (TIB IWF 12485); and the vetting results of the U.S. Office for Military Government for Germany, 1948 (TIB IWF 12863).

15 This can be shown from a comparison of the correspondence between Prandtl and the RfdU about the used material, the narrative structure and the intertitles (AMPG I/44/1305; AMPG I/44/1306).

16 "Die Frage ist aus dem Grunde besonders kompliziert, weil sicher eine beträchtliche Anzahl unserer Filme Professoren als Autoren haben, die jetzt wegen ihrer politischen Einstellung nicht mehr im Amt sind. Es wäre ein ausserordentlicher Verlust, wenn alle diese Filme im Unterricht nicht mehr eingesetzt werden dürften. Vielleicht müsste in einzelnen Fällen von der Möglichkeit Gebrauch gemacht werden, die Namen der Sachbearbeiter nicht mehr in Erscheinung treten zu lassen, sondern nur noch das Institut, aus dem sie stammen." Wolf to Schmid, 1947 (TIB IWF 12848).

17 Edgardo N. Accinelli to Prandtl, 1939 (AMPG I/44/209).

18 However, it should be pointed out that sometimes reused image sections (to a certain extent the rigid equivalent to the scene/sequence of a film) can also retain their connection to the image from which they are taken. Just think of the ubiquitous angels of the Sistine Madonna. Such reuses are usually only reserved for this type of blockbuster image.

19 This resonates with the discussion on the extent to which scientific films can be grasped as "immutable mobiles" (Latour) or "boundary objects" (Star and Griesemer) (Hoof 2014, 57–59).