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A Persistent Riddle in Historical Perspective

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Preface

Turbulence belongs to the realm of fluid dynamics, a discipline founded on the solid pillars of classical mechanics. Its basic equations, the Navier–Stokes equations, have been established in the nineteenth century. Yet it is regarded as the last major unsolved problem of classical physics. The turbulence problem rose to prominence as one of the most persistent challenges of science. The eddies in the turbulent flow of a river or the smoke from a chimney elude a physical understanding from first principles.

In the course of the twentieth century, turbulence became a research field where high expectations met with recurrent frustration. This makes turbulence an ideal subject for the historian of science and technology. On the route towards a history of turbulence, this book is focused on what the actors in this research field perceived as the turbulence problem. At different times and in different social and disciplinary environments, the nature of this problem changed in response to changing research agendas.

When the participants in this quest review their research field, they focus on the progress made for solving the riddles of turbulence. In contrast to participants' reviews, my emphasis is rather on the broader context in which the turbulence problem(s) became enunciated. I am aiming for historical authenticity by quoting as far as possible from contemporary sources (letters, reports, papers). If the original quote was in German, I translated it in English (indicated by "Translation ME" in the footnote). My narrative is descriptive and proceeds in chronological order from around 1900 to the last decade of the twentieth century, so that one or another variant of the turbulence problem will be revisited in subsequent chapters in different circumstances. I do not aim at a comprehensive account but rather at an exemplary exposition of the environments in which problems become items of research agendas. From this perspective, the turbulence problem also provides more general lessons for the history and epistemology of science and technology in the twentieth century.

Munich, Germany
August 2019

Michael Eckert

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Abbreviations

AIP	American Institute of Physics, College Park, MD
APS	American Physical Society
ASWB	Arnold Sommerfeld. Wissenschaftlicher Briefwechsel. Band I: 1892–1918; Band II: 1919–1951. Herausgegeben von Michael Eckert und Karl Märker. München, Berlin, Diepholz: Deutsches Museum und GNT-Verlag, 2000 und 2004
DFD	Division of Fluid Dynamics of the American Physical Society
DFDA	Division of Fluid Dynamics of the American Physical Society, Archives, Lehigh University, Bethlehem, Pennsylvania
DLR	Deutsches Zentrum für Luft- und Raumfahrt
DMA	Deutsches Museum, Archiv, München
GAMM	Gesellschaft für Angewandte Mathematik und Mechanik
GOAR	Historical Archive of the DLR, Göttingen
IAS	Institute of the Aeronautical Sciences, New York
IAU	International Astronomical Union
IUGG	International Union of Geodesy and Geophysics
IUTAM	International Union of Theoretical and Applied Mechanics
NACA	National Advisory Committee for Aeronautics, Washington, D.C.
NPL	National Physical Laboratory, Teddington
RANH	Rijksarchief in Noord-Holland, Haarlem
SUB	Niedersächsische Staats- und Universitätsbibliothek, Göttingen
TKC	Theodore von Kármán Collection, California Institute of Technology, Pasadena
ZAMM	Zeitschrift für Angewandte Mathematik und Mechanik
ZWB	Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters

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Chapter 1
Hydrodynamics Versus Hydraulics

Abstract In the beginning of the 20th century the study of fluid motion fell into one of two classes: either the observed flow could be described in terms of hydrodynamics, or it eluded theory and belonged to the realm of hydraulic engineering, like pipe- or channel flow. The discrepant results of hydrodynamics versus hydraulics illustrated the gulf between theory and practice—and turbulence was regarded as the culprit. The rise of aeronautics added further challenges. Wind tunnel investigations hinted at turbulence effects that eluded theoretical analysis.

Research on turbulence has no clear-cut beginning. The history of quantum mechanics, by comparison, may be confined to the time span between Max Planck's formula for black-body radiation in 1900 and the mid 1920s when Werner Heisenberg, Erwin Schrödinger and others established matrix- and wave mechanics. The history of turbulence has no such landmarks.

1.1 When and How Turbulence Became a Problem

Turbulent flow must have been observed since antiquity. It was surely perceived as strikingly different from the smooth flow regime later called laminar. The earliest observations of turbulence that left a trace in historic records are due to Leonardo da Vinci whose sketches of eddying water flow are frequently used in reviews on turbulence.[1] With the rise of "rational fluid mechanics" (Truesdell 1954) in the 18th century flow phenomena became subject of mathematical analysis. Johann and Daniel Bernoulli, Leonhard Euler, Jean-Baptiste le Rond d'Alembert and other pioneers of ideal flow theory must have been aware that there was a fundamental mismatch between theory and experiment which nearly always concerned eddying flow. "Euler's equation" for ideal flow was extended in the first half of the 19th century to

[1] See, for example, Tennekes and Lumley (1972), Frisch (1995), Ecke (2005) and websites such as http://sersol.weebly.com/workshop/leonardo-da-vinci-and-physics-of-fluid (24 October 2019).

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