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THE AMERICAN MATHEMATICAL SOCIETY AND APPLIED MATHEMATICS FROM THE 1920s TO THE 1950s: A REVISIONIST ACCOUNT

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Abstract. The "standard" historical narrative has it that: 1) applied mathematics emerged as an academic discipline in the United States only after, and as a result of, World War II; and 2) a major factor in this emergence was the presence of European émigré mathematicians. While this standard narrative is not wrong, it masks a key part of the picture, namely, the foundation for this development was laid within the context of the American Mathematical Society in the 1920s, 1930s, and 1940s.

The New York (after 1894, American) Mathematical Society (AMS) was founded in New York City in November 1888 by three then-recent Columbia graduate students—Thomas Fiske, Harold Jacoby, and Edward Stabler—"for the purpose of preserving, supplementing, and utilizing the results of their mathematical studies" [4, p. 4]. Their initiative aimed to produce on American shores "the feeling of comradeship among those interested in mathematics" that Fiske had experienced at meetings of the London Mathematical Society during a study trip to England [4, p. 4]. The young men saw their new society as a vehicle for "the discussion of mathematical subjects, the criticism of current mathematical literature, and the solution of problems proposed by its members and correspondents" as well as for the presentation of "original investigations to which [its] members may be led" [4, p. 4].

Six people answered their call to an organizational meeting, but a year later, the Society had just sixteen members. Of them, though, more than half—including Jacoby and Stabler—applied mathematics in their work: as actuaries, astronomers and/or geodesists, and engineers. Others of an applied bent, like the Breslau-born, General Electric engineer Charles Steinmetz, also joined and participated in the early activities of the AMS. Yet, as the Society grew and developed into the opening decades of the twentieth century, it seemed evident that "practically all of its publications and most of the papers presented at its meetings [were] in the field of technical pure mathematics" [4, p. 88]. In short, applied mathematics, in the sense that Joachim Weyl would later describe as "the creation, the adaptation and the communication of mathematics, inspired by and knowingly related to the effort of advancing our rational understanding of some aspect of the world around us", was hardly in evidence [84, p. 1]. That definition of applied mathematics reflected "a matter of attitude and motivation, not of subject matter" and was largely not part of the AMS's early ethos [84, p. 1].

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In many regards, this had been a natural evolution, given that the 1890s had witnessed the European, and particularly more purist German, doctoral education of many who constituted what may be considered the first generation of American research mathematicians. It was mathematicians of this bent—as opposed to the Jacobys and Stablers educated at home—who had come back to the United States and made common cause to shape a venue supportive of their research interests. That decade also saw the transplantation of those newly trained mathematicians to programs at the growing number of universities in the Northeast and beyond which increasingly measured their competitiveness in terms of the strength of the research they generated and the graduate programs they built.[1] As these mathematicians steadily grew in number, they passed on their interests and ideals to their students and, together, came to dominate the AMS.

The evolution was also natural because in the decades on either side of 1900 in the decentralized United States as opposed, say, to more administratively coordinated Germany, formal ties between engineering education and mathematics education were tenuous to nonexistent (see [72] and [74]). Indeed, prior to 1940, "most engineering colleges remained wedded to the traditional approach of practical education and research" instead of paying "greater attention to scientific fundamentals" [72, p. 366]. Had there been an emphasis on those "fundamentals", there would likely have been, as in Germany, pressures both internal and external to the mathematical community exerted for training in and the academic development of applied mathematics [74, p. 119].

It is not surprising, then, that the now-standard historical narrative, which interprets the development of applied mathematics in the United States in terms of "systematic research and training in academic surroundings" [74, p. 116], describes a dramatic "rise" in the field in the United States following the successes of mathematicians, physicists, chemists, and others working in concert during and immediately after World War II [18]. The standard narrative is not wrong. Applied mathematics as an *academic* discipline in the United States *was* stimulated by World War II as well as by the mathematical acculturation, immediately before and after the war, of a number of key European émigrés, among them, Theodore von Kármán, Richard Courant, John von Neumann, and Richard von Mises. Still, implicit in that narrative is the theme of a United States lagging behind other nations, especially Germany, in applied mathematics because, largely, of the "purity" of American mathematics.[2] And, since the AMS was the organizational face of the

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[1] David Rowe and I treated these developments in [53].

[2] Among other places, this view is expressed in [18, pp. 153–154], [42, pp. 455–456], [74, pp. 119–120], [73, p. 793]. In addition to "purity", Siegmund-Schultze isolated and discussed three other, lesser sociological theses posited by scholars for this phenomenon: 1) "abundance", that is, since natural resources were abundant in the United States, engineers were not compelled to implement more sophisticated mathematical methods; 2) "anti-modernism", that is, mathematicians saw applications as a prostitution of their field; and 3) "military spin-off", that is, because there was little military research in the United States before World War I, applied mathematics had not been tapped. See [74, pp. 117–118]. Even more recently, Ellen Abrams has given a gendered interpretation, arguing that "[b]y choosing to encode their professional identities in the ideals of modern abstractions,... mathematicians in the United States forfeited access to traditional forms of masculinity that were associated with military or industrial applications. Instead, they marshalled other forms of manliness tied to nostalgic traditions of farm work, rugged individualism, and, eventually, professional exclusivity and prestige" [1, p. 24].

American mathematical research community, the failure adequately to promote applied mathematics in the United States prior to World War II has been laid at its institutional doorstep (see, for example, [89, pp. 414–415] and [84, p. 58]).

Yet, it is indisputable that the AMS founded its Josiah Willard Gibbs Lectureship in 1923 as an annual event explicitly to honor the renowned nineteenth-century Yale mathematician's sophisticated and often applied work as well as to give "a larger public, in semi-popular form, some idea of aspects of mathematics and its applications" [4, p. 88]. It is also indisputable that in 1953, the AMS—and not the Society for Industrial and Applied Mathematics that had been founded in 1951 but that only began to host national meetings in 1954—provided the framework within which two symposia on training and research in applied mathematics, under the aegis of the National Research Council (NRC), were held. They served to anchor the survey on "Training and Research in Applied Mathematics in the United States" on which Joachim Weyl reported the following year [84]. Clearly, then, the AMS *was* doing *something* to foster applied mathematics in the United States from the 1920s into the 1950s. A closer look at its actual activities over that roughly thirty-year period refines the standard narrative in key ways.

The Josiah Willard Gibbs Lectureship

The AMS established its Josiah Willard Gibbs Lectureship in the aftermath of World War I as the American mathematical research community that it represented sought to compete with the other sciences, and particularly physics and chemistry, for both public recognition and emergent funding. In particular, the NRC, founded as an arm of the National Academy of Sciences in 1916 but reorganized in 1919, received money from both the Carnegie Corporation of New York and the Rockefeller Foundation to support its overall mission of "promot[ing] research in the mathematical, physical, and biological sciences, and in the *application* of these sciences to engineering, agriculture, medicine, and other useful arts, with the object of increasing knowledge, of strengthening the national defense, and of contributing in other ways to the public welfare".[3] As President of the AMS in 1923 and 1924, Princeton mathematician Oswald Veblen sought to position the AMS strategically in a fast-evolving national scientific scene increasingly characterized by both the NRC and the foundations that underwrote it. In addition to overseeing a fund-raising campaign aimed at putting the AMS and its publications on a firmer financial footing, he argued for the creation of the Gibbs Lectures to highlight the interrelation, specifically, between mathematics and its multifarious applications.[4] In particular, he argued that his own special field, "the foundations of geometry", "*must* be studied *both* as a branch of physics *and* as a branch of mathematics" [80, p. 121 (my emphases)]. His right-hand man as Secretary of the AMS, Roland Richardson, concurred and called for even more. He advocated "the building up of a school of applied mathematics" in the United States, viewing that,

[3]For the quotation, see [3, p. 458] and [9, p. 7] (my emphasis). I discuss this development in broader historical context in [51].

[4]Loren Butler Feffer treated the fund-raising campaign in [22]. On efforts in the 1920s to improve the infrastructure of mathematics in general, see [50, pp. 63–93].

in 1924, as "our most pressing need at present".[5] There was thus a certain momentum within the AMS in the early 1920s for the promotion of applied mathematics that the Gibbs Lectures made manifest.[6]

The Serbian-born, Columbia physicist and electrical engineer, Michael Pupin, delivered the first Gibbs Lecture in 1924, the year after publishing the autobiography, *From Immigrant to Inventor*, for which he would win a 1924 Pulitzer Prize [58]. If Veblen and his colleagues wanted an inaugural speaker who could communicate effectively to a broad audience about the mathematical sciences, Pupin was certainly an excellent choice.

By way of introduction, Veblen set the stage for Pupin's talk, explaining that, through the Gibbs Lectures, "the American Mathematical Society has recognized the dual character of mathematics. On the one hand, mathematics is one of the essential emanations of the human spirit—a thing to be valued in and for itself, like art or poetry. ... On the other hand, mathematics is the handmaiden and helper of the sciences, both in their most abstract generalizations and in their most concrete applications to industry" [65, p. 289]. "It is hoped", he continued, "that the Willard Gibbs Lectures will remind the mathematicians of something that we fear they sometimes forget—the existence of an outside world. It is equally hoped that they will remind the outside world that mathematics is a going concern—not a pedantic exercise for the torment of school boys, but a living organism growing larger and stronger each year" [65, p. 289].

The audience, described as "large and distinguished", that assembled to hear Pupin speak on "Co-ordination" was comprised of members of the AMS as well as the "many physicists, chemists, and engineers who had been invited to attend" [65, p. 289]. After a brief tour of the history of dynamics from the ancient Greeks to Newton, Pupin defined "co-ordination" to mean "what the Greeks called *Cosmos*; that is, a creation of law and order, in contradistinction to *Chaos*, which denoted to the Greek mind a shapeless mass devoid of all intelligible law and order" [57, p. 4 (his emphases)].[7] "Non-co-ordination" then corresponded to chaos, and Pupin proceeded to illustrate both concepts by contrasting Newton's and Maxwell's mathematization of the "macrocosm" or "large-scale world" with the mathematical exploration, beginning in the early nineteenth century by figures such as French engineer Sadi Carnot and later Willard Gibbs, of the "microcosm" as reflected in the uncoordinated motion of molecules in a hot body, that is, thermodynamics [57, p. 5]. Newton and Maxwell dealt with the coordinated cosmos; Carnot and

[5]Richardson to Veblen, 19 July, 1924, HUA 4213.2, Box 4, Folder: Correspondence 1924 N-Q, Birkhoff Papers. Richardson would, in fact, realize this goal at Brown University in the 1940s. See below.

[6]Despite Veblen's advocacy for the Gibbs Lectures, his public acknowledgment of the tight interrelations between geometry and physics, and his building, with Luther Eisenhart, of the program in geometry applied to the theory of relativity at Princeton [71], Veblen has repeatedly been cast in the literature as a voice against applied mathematics within the American mathematical community. The oft-cited quotation, however, is from a 1929 personal letter from Veblen to Richardson: "I do not believe that there is, properly speaking, such a thing as applied mathematics. There is a British illusion to that effect. But there is such a thing as physics in which mathematics is freely used as a tool. There is also engineering, chemistry, economics, etc., in which mathematics plays a similar role, but the interest of all these sciences are distinct from each other and from mathematics". See, for example, [59, p. 197], [18, pp. 153–154], and [21, p. 79].

[7]The title of the published version of Pupin's talk, "From Chaos to Cosmos", was much more evocative than its original title!

Gibbs with uncoordinated chaos. Gibbs, Pupin argued, "may be called the Newton of chemical and caloric dynamics, the dynamics of non-co-ordination, and it was he who gave us a mathematical method by which we can calculate in any particular case that part of the non-co-ordinated energy of any form which is available for co-ordinated external service" [57, pp. 6–7]. The moral of Pupin's story was that, surprisingly, mathematics underlay both cosmos and chaos, and therein lay its power for understanding and interpreting the world around us.

This was a good lesson. It gave the mathematicians in the audience a certain amount of ammunition in their efforts to promote their often misunderstood and underappreciated field in the new climate of financial support for science, while it underscored for the audience's other scientists the debt that their work ultimately owed to mathematics. It provided common ground for mutual understanding.

Mathematical physics themes like Pupin's dominated the Gibbs Lectures especially in the 1930s as Einstein's work continued to generate interest, both popular and scientific.[8] Three consecutive lectures—in 1931, 1932, and 1934 (there was no Gibbs Lecture in 1933)—dealt with aspects of then-modern physics. In 1931, Harvard physicist, Percy Bridgman considered "Statistical Mechanics and the Second Law of Thermodynamics" in order to explore "a few of the implications and consequences of the statistical point of view" in interpreting the natural world [12, p. 226]. He was followed in 1932 by Caltech physicist and physical chemist, Richard Tolman, who gave what was described as the "brilliant" lecture [61, p. 162] on "Thermodynamics and Relativity", in which he laid out why, "[i]n order . . . to investigate the thermodynamic behavior of large portions of the universe as we may wish to do in connection with cosmological problems, and in order to obtain even in the case of small systems more precise expressions for the thermodynamic effects of gravity, it becomes necessary to extend thermodynamics to general relativity, and to make use of the more valid ideas as to the nature of space and time and the more precise theory of gravitation which Einstein has now provided" [79, pp. 49–50].

These two talks, in some sense, set the stage for that of the master himself, the Institute for Advanced Study's Albert Einstein, in 1934. The audience for Einstein's much more technical presentation on an "Elementary Derivation of the Equivalence of Mass and Energy" was likely less interested in the details of his mathematical argument than in seeing the living legend in action. Interestingly, though, Einstein's talk closed with evidence of an exchange with Harvard's George Birkhoff, one of the leading American mathematicians of the first half of the twentieth century, in which Birkhoff claimed priority for the derivation Einstein presented. "In spite of this", Einstein stated, "I believe that the present derivations merit a certain amount of interest" [20, p. 230]. While Einstein publicly acknowledged that Birkhoff and his student Rudolph Langer may have included "quite similar considerations" in their 1923 book *Relativity and Modern Physics* [11], they made "essential use . . . of the concept of *force*, which in relativity theory has no such direct significance as it has in classical mechanics" [20, p. 230 (his emphasis)]. Einstein, therefore, not only "avoided using the force concept" but also "was concerned with avoiding

[8]Not surprisingly, given the importance of physics in World War II, this theme persisted into the 1940s with talks in 1944 by the Institute for Advanced Study's John von Neumann on "The Ergodic Theorem and Statistical Mechanics" and in 1945 by MIT's John Slater on "Physics and the Wave Equation". Although the press of war work and then his involvement in electronic computing prevented von Neumann from ever writing up his talk for publication, Slater's talk appeared in the *Bulletin of the American Mathematical Society* [75].

making any assumption concerning the transformation character of impulse and energy with respect to a Lorentz transformation" [20, p. 230]. This was a polite rebuke, but a rebuke none the less.

Although it has been argued that when they thought about it at all, American mathematicians tended actually to *equate* applied mathematics with mathematical physics [21], the range of topics treated in the Gibbs Lectures suggested that they appreciated that their subject had a much greater reach. Pupin's Gibbs Lecture was followed in 1924 by an address on "Life Insurance as a Social Service and as a Mathematical Problem" by Robert Henderson, the Vice President of the Equitable Life Assurance Society in New York City and one of the AMS's Trustees [29]. By stressing both that "the science of life contingencies [is] an application of mathematics" and that "life assurance performs a very important social service", he underscored what he viewed as at least one key aspect of mathematics' social relevance [29, pp. 232 and 227, respectively]. Yale economist Irving Fisher sounded a similar theme five years later in his 1929 lecture on "Mathematics and the Social Sciences" [23], while Harvard economist Wassily Leontief was even more focused in 1953 when he spoke on "Mathematics in Economics" [43].

And, then, of course, there was mathematics as applied to the other sciences. Gibbs Lecture audiences—consistently numbering around 300 by the 1940s—heard a talk on mathematical applications to astronomy in each of the decades of the 1920s, 1930s, and 1940s, to biology in 1926 and 1941, and to chemistry in 1937.[9] In the lead-up to and aftermath of World War II, the connections between mathematics and various aspects of engineering were also highlighted by, for example, MIT electrical engineer and computing machine pioneer, Vannevar Bush, in 1936, Caltech aerodynamical engineer, Theodore von Kármán, in 1939, and Caltech applied mathematician, Harry Bateman, in 1943. World War II sparked the development, too, of new applied areas like operations research, the topic of the Gibbs Lecture that MIT physicist Philip Morse delivered in 1947.

Finally, what might be called "applicable"—as opposed to "applied"—mathematics served to focus at least two of the Gibbs Lectures in the 1920s through the early 1950s. In 1925 in the third lecture in the series, entitled "Some Modern Views of Space", Yale mathematician, James Pierpont, surveyed mathematizations of space from Euclid to Lobachevsky and Bolyai to Riemann to Ricci, Levi-Civita, and Weyl to Minkowski and others. Most of this mathematics, he argued, was discovered independently of immediate applications, yet, for example, "Einstein found ready for use" the tensor analysis of Ricci and Levi-Civita "without which there would have been no general theory of relativity" [54, p. 246]. Their work, like potentially all "pure" mathematics, was thus "applicable", even if it only became "applied" later. Similarly, in 1949, Hermann Weyl focused on various of the uses that had been made in physics of the mathematical theory of eigenvalues in his discussion of "Ramifications, Old and New, of the Eigenvalue Problem" [81]. In short, these could be interpreted as examples of what physicist, Eugene Wigner, would later describe as "the unreasonable effectiveness of mathematics in the natural sciences" [88, p. 1].

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[9] Attendance figures were sometimes published in the final report on the AMS's annual meeting. See, for example, [33, p. 26]. The fact that over 200 people registered for that meeting but 300 people attended the Gibbs Lectures gives a certain measure of the lecture's draw. For a full list of the Gibbs Lecturers, their titles and, in many instances, the places of publication of their talks, see `http://www.ams.org/meetings/lectures/meet-gibbs-lect`.

Two Gibbs lecturers in the series' first thirty years, however, seemed to have eschewed the mandate of providing to "a larger public, in semi-popular form, some idea of aspects of mathematics *and* its applications" [4, p. 88 (my emphasis)]. The famously "pure" mathematician, G. H. Hardy, who, given his Platonist view that pure mathematics deals with a mathematical reality and so is, by definition, applied, unabashedly highlighted in his 1928 Gibbs Lecture what most in his audience would have viewed as the purest of the pure, namely, number theory.[10] Although illness ultimately prevented him from personally delivering his "Introduction to the Theory of Numbers" (it was given in his absence by Heinrich Brinkmann, then an assistant professor at Harvard), Hardy wanted his audience to appreciate what he viewed as the fact that "[t]he theory of numbers has always occupied a peculiar position among the purely mathematical sciences. It has the reputation of great difficulty and mystery among many who would be competent to judge", yet "[a]t the same time it is unique among mathematical theories in its appeal to the uninstructed imagination and in its fascination for the amateur" [27, p. 778]. His, then, would be a talk for those who "are curious about the properties of integral numbers" [27, p. 782]. Nothing more, nothing less. If, though, number theory were to be applied in some non-Platonic sense, Hardy held that it "should be one of the very best subjects for early mathematical instruction" [27, p. 818]. Indeed, in his view, "[a] month's intelligent instruction [in it] ought to be twice as instructive, twice as useful, and at least ten times as entertaining as the same amount of 'calculus for engineers'" [27, p. 818].[11]

While only a mathematician as renowned, as quirky, and as opinionated as Hardy might have spun a Gibbs Lecture in exactly this way, another equally renowned and quirky mathematician, Kurt Gödel, took a different "contrarian" tack. In his 1951 Gibbs Lecture on "Some Basic Theorems on the Foundations of Mathematics and Their Philosophical Implications", Gödel highlighted, in some sense, the *limits* of mathematics' applicability.[12] As his 1931 incompleteness theorem had shown, there is, in any given formal system, at least one true theorem that is mathematically unprovable. After exploring with his audience some of the implications of this fact, Gödel moved on to even more philosophical considerations. He, more explicitly than had Hardy, championed Platonism or, in his view, the philosophical stance that mathematical objects and "concepts form an objective reality of their own, which we cannot create or change, but only perceive and describe" [25, p. 320].

Although, on the whole, it is hard to gauge the impact of these, the earliest, Gibbs Lectures, a few things can be said about them in relation to the question of the AMS and applied mathematics in the interwar and immediately postwar periods. Given the continued dominance of pure mathematics in the publications and meetings of the AMS, it seems clear that the Gibbs Lectures did not reorient large numbers of the AMS membership from pure to more applied topics. That, however, was

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[10] Hardy was not alone in this belief about number theory. Gödel, as noted in the next paragraph, also adhered to it, and in an interview with Don Albers, Freeman Dyson asserted that "number theory is applied mathematics. ... You're not creating ideas; you're just applying methods and using numbers as your experimental material" [2, p. 12].

[11] Of course, in 1928, Hardy had no idea of the profound applications, again in the non-Platonic sense, number theory would later have in such areas as cryptography and cybersecurity.

[12] This was the title of Gödel's actual Gibbs lecture. Never published at the time, it appeared in print only in Gödel's *Collected Works* under the title "Some Basic Theorems on the Foundations of Mathematics and Their Implications".

not their purpose. Although they sought to give whatever non-mathematicians might be in the audience an appreciation of mathematics' power to interpret the natural world, they primarily aimed to educate the AMS membership, to give it a deeper sense both of mathematics' reach as a field and of applications *per se*, to provide examples of the applicability of mathematics that the broader public would understand, and, as Veblen put it, to "remind" pure mathematicians of "the existence of an outside world" [65, p. 289]. In so doing, they aimed primarily to equip mathematicians for more effective communication with other scientists as well as with those non-mathematicians who held the philanthropic and, after World War II, governmental purse strings.

Applied mathematics in the meetings of the AMS

Another means both to educate mathematicians about applied mathematics and to support research in the area was, of course, through talks at the AMS's meetings. Indeed, applied mathematics, in Joachim Weyl's fulsome sense of the phrase, was actually already under discussion at meetings of the AMS even in its earliest days. The second AMS President, actuary Emory McClintock, for example, chose, in his retiring presidential address on 28 December 1894, to contemplate "The Past and Future of the Society" and, in so doing, highlighted applied mathematics. As he saw it, among its various roles, the AMS fostered "original mathematical research", yet that meant research "either in pure or in applied mathematics" [45, p. 92].[13] Although he readily acknowledged that "[b]y far the greater number of papers relate to the former class of investigations", he felt "that greater opportunities for attaining important results lie in the latter direction" since "many important improvements in pure mathematics are the direct result of efforts connected with practical applications" [45, p. 92]. This should have been enough, in his view, to encourage research in applied mathematics but for the fact that in the United States there was "much wider dissemination of elementary instruction in pure mathematics as compared with applied" so that "by far the greater number of investigations thus far have related to pure mathematics; and it may be presumed that for some time to come this disproportion will continue" [45, p. 93].

A number of McClintock's successors also sounded applied mathematical themes in their retiring presidential addresses into the early twentieth century. For example, the third AMS President, celestial mechanist George William Hill, spoke in 1895 on progress in his field since the middle of the nineteenth century [30]; the fifth, astronomer/geodesist/physicist Robert Woodward, took on the even broader topic of "The Century's Progress in Applied Mathematics" in 1899 [90]; the thirteenth, celestial mechanist Ernest Brown, explored "The Relation of Mathematics to the Natural Sciences" seventeen years later [13].[14] Indeed, all of these talks were in,

[13]I discuss McClintock's and other early AMS presidential addresses in [52, especially pp. 384–385].

[14]The sixth president, pure mathematician Eliakim Hastings Moore, broached an even more basic issue, mathematics instruction, in his 1902 address. There, he argued that more emphasis needed to be given to "the practical sides of mathematics, that is, arithmetic computations, mechanical drawing and graphical methods generally, in continuous relation with problems of physics and chemistry and engineering" [47, p. 407]. This position would be in accord both with the formation in 1914 of MIT's applied mathematics laboratory (see the next section) and with conclusions of the symposium on training in applied mathematics sponsored in 1953 by the National Research Council in conjunction with the AMS (see the final section).

what would come to be after 1923, the spirit of the Gibbs Lectures. The latter two, moreover, actually offered cogent arguments for the greater encouragement of applied mathematical work *per se* in the United States, while continuing to foster research in more purist veins. Woodward put it succinctly: "I would not be understood as urging the cultivation of pure mathematics less, but rather as suggesting the pursuit of applied mathematics more" [90, p. 163]. Throughout the 1920s to the 1950s, applied mathematics continued to maintain—and with actual technical talks—the modest presence that it had essentially had since the beginning in meetings of the AMS.

Consider first the 1920s. Scanning the titles and abstracts of the talks given at the AMS's annual meetings in that decade reveals a not insignificant number of applied mathematical contributions. Relatively speaking, the decade started out strong. Of the forty-five papers presented either in person or by title at the 1920 meeting held at Columbia in December, eight or just over 17% could be classified as "applied mathematics" *à la* Weyl [67, pp. 248ff]. Specifically, Charles Wilder, then an assistant professor at Northwestern, treated Einstein's four-dimensional space; Joseph Rowe, chief ballistician at Maryland's Aberdeen Proving Ground from 1920 to 1921, discussed "The Efficiency of Projectile and Gun"; Harvard's Edward Huntington developed "A Mathematical Theory of Proportional Representation"; Edward Kasner of Columbia considered, in two different papers, "Properties of Orbits in the General Theory of Relativity" and "The Solar Gravitational Field in Finite Form"; and Chester Forsyth of Dartmouth, also in two separate papers, explored the financial instrument, bonds, and how to calculate rate of return under various initial conditions.

The next year, 1921, also witnessed a measurable applied mathematics presence when the Society met jointly with the American Association for the Advancement of Science (AAAS) in Toronto. There, in addition to a symposium on quantum theory featuring a Richard Tolman then with the Ordnance Department in Washington, DC, MIT mathematician Henry Phillips, and physicist Saul Dushman, a member of the research laboratory at the General Electric Company, attendees had the opportunity to hear seven talks of an applied nature or 21% of the papers read as part of the regular meeting [68, p. 152ff]. A year later, the numbers had fallen off to just under 10% with three of the thirty-two talks delivered on applied topics: irreversible systems in dynamics, a nonlinear partial regression equation, and the method of least squares [69, pp. 102ff].

By 1923, the AMS was distinguishing in its meeting reporting between papers delivered by title only and those delivered in person. Considering only the latter, since those would have been the ones that other members of the Society in attendance could actually have heard and been influenced by, two of twenty-six talks, or slightly less than 8%, were applied: Michigan's George Rainich on Maxwell's equations and general relativity and Forsyth on the mathematical theory of finance. Although percentages on either side of 10% were more typical of applied mathematical representation in meetings of the AMS in the 1920s, in 1928, "[m]ore than 400 persons, a much larger number than had been anticipated, including chemists as well as mathematicians and physicists", were present at "a symposium on quantum mechanics, under the joint auspices of the" AMS and the American Physical Society [64, p. 163]. And, of the sixty-one talks given in person in the regular part of that meeting, nine or 14% were applied in nature on topics ranging from statistics to dynamics to engineering ballistics to Volterra's mathematical theory of biological associations to economics.

The next year, in 1929, the AMS itself began roughly to classify into "sections" the various talks given at its meetings. At that year's annual meeting, ten talks were given in person in the oddly grouped "Section on Applications and Algebra", of which six or over 13% of the forty-three talks given in person during the "regular" part of the meeting were on the former: Harold Hotelling, then an associate professor at Stanford, spoke on "Spaces of Statistical Parameters"; George Washington University statistician Frank Weida considered the valuation of a continuous survivorship annuity under certain conditions; R. L. Peek of Bell Labs dealt with the general equation of diffusion; consulting engineer, Benjamin Groat, treated what he termed "Newtonian similarity"; and two were specifically engineering-related [62, p. 153]. The 1929 gathering, like the one the year before, also included a special symposium, this time on the "differential equations of engineering" [62, p. 150]. According to Roland Richardson, "[t]his part of the program [had been] arranged because of a wish expressed by some members of each of the two groups—mathematicians and research engineers—for closer cooperation" [66]. "Many engineers were present by invitation" at the event, and "[t]here was much interesting and illuminating discussion" of the five papers presented: Wisconsin mathematician, Herbert March, on the problem of diffusion; MIT's Bush on the mechanical solution of differential equations; Arpad Nadai, consulting mechanical engineer at the Westinghouse Corporation, on the plasticity of non-rigid bodies; Robert Park, electrical engineer with the Stone and Webster Corporation, on the analytical determination of magnetic fields; and then University of Michigan mechanical engineer, Stephen Timoshenko, on problems in elasticity [62, p. 150].[15]

Immediately on the heels of this symposium, early in 1930, the AMS appointed a committee "to investigate the need for a journal of applied mathematics" [4, p. 17]. Comprised of Philip Alger of General Electric, Tomlinson Fort of Lehigh University, Thornton Fry of Bell Labs, Timoshenko, Wisconsin's Warren Weaver, and Norbert Wiener of MIT, the committee recommended and the AMS Council approved the creation of a new "Journal of Applied Mathematics" that would be a joint venture between the AMS, MIT, the American Institute of Electrical Engineers, the American Society of Mechanical Engineers, and perhaps other societies. The early months, however, of what stretched through the 1930s into the Great Depression proved an inauspicious time to launch such an initiative. When "economic conditions in the country" thus "led to the withdrawal of financial support which the committee had good reason to think would have been forthcoming from cooperating organizations", "the project had to be abandoned" [4, p. 18]. The AMS had tried to take a major step toward the active promotion and encouragement of applied mathematics in the United States in 1930, but the stock market crash ultimately thwarted its efforts.

"Applications" nevertheless continued to appear in section categorizations at the AMS's annual meetings throughout the troubled decade of the 1930s, although not in 1930 (when "probability and other topics" constituted the meeting's more applicable content) or in 1933, 1936, and 1937 (when the rubric was "statistics"). The representation of applied mathematical topics fluctuated between a low of

[15]There was to have been a sixth talk by Thomas Gronwall, mathematician then in the physics department at Columbia University. See [66]. For more on Gronwall, see [24].

less than 1% of the talks delivered at the height of the Depression in 1933 and again in 1936 when the AMS met in North Carolina in the Jim Crow South to a high of just at 33% in 1931 when there were special lectures joint with both the American Physical Society and the AAAS. In between, numbers averaged roughly 10%, but this owed more to the presence of talks in probability and especially mathematical statistics than to those on engineering, actuarial, or other types of applied mathematics. Still, during the 1930s as in the 1920s, special symposia of an applied nature repeatedly supplemented the offerings of regular talks: in 1932 on the application of the operational calculus to mechanics [61], on probability in 1933 [63], on statistics as well as on group theory and quantum mechanics in 1934 [39], and on applied mathematics in 1939 [5]. Additionally, of the some 204 invited addresses given before meetings of the AMS between April 1921 and April 1938, thirty-six or 17% were in applied mathematics [49, p. 434].

As the 1930s lengthened and war first loomed and then broke out in Europe, the American mathematical research community as represented by the AMS began to focus on its potential role in wartime. As early as 1939, then AMS President, Berkeley's Griffith Evans, pushed for the immediate creation of a War Preparedness Committee (WPC) to be joint with the Mathematical Association of America (MAA).[16] By tapping the expertise of the research-oriented AMS as well as the more teaching-oriented MAA in creating the WPC, Evans and his MAA presidential counterpart, Walter Carver, recognized that mathematicians would be needed in time of war both as problem-solvers and as teachers. Familiarity with and expertise in applied mathematics would be important in each of these roles.

Specifically to this end, by 1940, the AMS had formed a Committee on Addresses in Applied Mathematics. Chaired by New York University (NYU) professor and 1934 German émigré, Richard Courant, it was charged with making "recommendations for a vigorous program in connection with the various meetings of mathematicians", both regional and national [6, p. 183]. In this way, applied mathematics would be brought more deliberately before the AMS membership.

Just months after its formation, Courant's committee organized three half-day symposia in order to expose those in attendance to various applied mathematical areas: the buckling of elastic plates, mathematical statistics in mass production, the Rayleigh-Ritz method and its applications, traveling waves, and two-dimensional problems in elasticity [55, p. 91]. That same year, the AMS also began more systematically to categorize the abstracts of papers submitted to any and all of its meetings for presentation either in person or by title. In addition to algebra, analysis, geometry, number theory, and topology, "applied mathematics" appeared as a category separate and distinct from "statistics and probability".[17]

World War II, however, fundamentally affected the ability of the AMS to do its work, as professional activities of all sorts were curtailed and meetings that were held were small. In 1942, for example, the AMS actually had to cancel its scheduled annual meeting "[i]n compliance with the request of the Office of Defense Transportation", and in 1945, only twenty talks were delivered in person with none in applied mathematics [40, p. 195]. Despite these logistical problems, an

[16] I discuss this committee in the context of the mobilization and participation of mathematicians in World War II in [50, pp. 340–350].

[17] See, for example, *Bulletin of the American Mathematical Society* **47** (1941), 30–58. Abstracts so categorized were collected and published in the odd-numbered issues of the *Bulletin* through 1947.

average of 9% of the talks at annual meetings from 1941 through 1945 dealt with applied mathematics as categorized by the AMS.[18] At the height of the war in 1944, Courant's committee also managed to mount at least one other applied symposium, this time featuring talks on the immediately war-related topics of hydrodynamical stability and the theory of elastic plates and shells [46, p. 476].

If the symposia held between 1941 and 1944 had a rather ad hoc quality, squeezed in as preparations for war were under way and, again, in the midst of wartime occupations, it was after the war's end, when the American mathematical community was able to resume its normal rhythm, that more systematic efforts were undertaken. In 1946, a special committee on applied mathematics was formed to advise the AMS Council on "next steps". By December, it had advised that a permanent committee on applied mathematics be created, that an annual symposium on applied mathematics be instituted, and that the feasibility of publishing the proceedings of those symposia be evaluated [55, p. 92]. It also prepared a white paper on "Instruction and Research in Applied Mathematics" in which it acknowledged that "there are relatively few opportunities for a student of mathematics, undergraduate or graduate, to become acquainted with the mathematical theories underlying other sciences", owing to the way in which the "educational system is at present organized", that is, in specialized, departmental units [76, p. 639]. As an antidote, it "suggested that departments of mathematics throughout the country should consider the feasibility of enlarging their offerings in the direction of applied mathematics", paying particular attention to "mathematical statistics, theoretical mechanics (including elasticity and fluid dynamics), statistical mechanics and thermodynamics, heat conduction, electromagnetic theory, relativity, quantum mechanics, genetics, and the theory of high polymers" [76, p. 640]. These were among the offerings that had already been incorporated in the 1920s and 1930s into programs like those at MIT, Michigan, Wisconsin, Iowa, NYU, and Caltech.

The AMS Council immediately acted on the special committee's recommendations by forming a new, postwar Committee on Applied Mathematics chaired by John Synge, the Dublin-trained head of the mathematics department at the Carnegie Institute of Technology from 1946 to 1948, with Courant, Evans, von Neumann, Weaver, and émigré William Prager of Brown as members. It began its work in 1947 [55, p. 92] and, by August, had mounted the first of what became a regular and sustained series of symposia on applied mathematics. "Non-linear Problems in Mechanics of Continua" was held at Brown with some 265 people in attendance to hear four invited addresses and twenty-one twenty-minute talks [56]. The papers were published in 1949 as the first volume in a new AMS series, *Proceedings of Symposia in Applied Mathematics* [60]. Other symposia followed annually [55, pp. 94–99].

These special activities served to enhance the individual talks given at the AMS's regular meetings throughout the 1940s, the abstracts of which, from 1941 through 1947 at least, were categorized by subfield in free-standing articles in the *Bulletin*.[19] In that seven-year period, just less than 150 different mathematicians, among whom were some twenty-two post-1933 émigrés (roughly 14%), offered their work on applied mathematical topics to the AMS. Slightly more than fifty of them did so twice

[18] The percentages are derived from the titles published in [32, pp. 192–193], [7, pp. 29–32], [33, pp. 32–34], and [14, pp. 41–43].

[19] Thereafter, the abstracts for each meeting were categorized in the individual meeting reports.

or more. Among their number were at least two women, émigrées Hilda Geiringer and Ida Roettinger (later Kaplan), and one African-American, physicist Herman Branson.[20] Moreover, between 1946 and 1951 when the Society for Industrial and Applied Mathematics (SIAM) was founded, the percentage of applied mathematical talks presented at the AMS's annual meetings averaged around 15% of the in-person program and continued to have an AMS presence through the 1950s, even after SIAM began mounting its own meetings in 1954.[21]

As the data presented here confirm, while applied mathematics was certainly never as prevalent as pure mathematics in the annual meetings of the AMS (it should be noted, however, that it was also represented in the Society's regional meetings), it was by no means negligible. American mathematicians of an applied bent clearly viewed the AMS, despite its predominantly purist orientation, as a viable outlet for the presentation of their work. And, if the AMS did not consistently encourage the pursuit of applied mathematics, it certainly did not discourage it. In fact, it worked to promote, recognize, and incorporate it into research-level mathematics in the United States.

The topography of applied mathematics as reflected in the AMS

A closer look at those speaking on applied mathematical topics at annual meetings of the AMS gives at least a sense of where "research and training in academic surroundings" *was* taking place in the United States in the three decades immediately following World War I, even if that research and training may not have been "systematic", that is, in the form of dedicated departments or programs [74, p. 116]. Over the course of the 1920s, for example, some twenty-seven mathematicians spoke on their applied mathematical work in the context of annual meetings of the AMS with nine of them giving two or more talks. Two of the latter, Norbert Wiener and Joseph Lipka, were at MIT, where the department of mathematics had close ties with both physics and electrical engineering and, since 1922, had published its own in-house *Journal of Mathematics and Physics* as "an outlet for papers in pure and applied mathematics by members of the Institute".[22]

Wiener, as is well-known, was a mathematician of eclectic tastes that bridged the pure and applied. In the 1920s, he presented work before the AMS on relativity (in 1927) joint with Dutch differential geometer, Dirk Struik, his colleague beginning in 1926, and on "Harmonic Analysis and Quantum Mechanics" as one of the featured speakers in the symposium on quantum mechanics sponsored by the AMS and the American Physical Society in December 1928 (see [19, p. 149] and [64, p. 163], respectively). Struik also served as one of that symposium's official discussants.

The Polish-born Lipka had come to the United States "at an early age" and had earned his PhD at Columbia in 1912 under Edward Kasner in the latter's brand of

[20] At least two women had given applied mathematical talks in the context of the AMS in the 1930s: one Daisy Starkey, who worked in mathematical statistics, and Ruth Struik, the wife of MIT's Dirk Struik and the first woman to earn (in 1919) a doctorate in mathematics at the German University in Prague [10].

[21] These percentages are derived from these meeting reports: [34, pp. 252–254], [41, pp. 283–286], [91, pp. 291–296], [86, pp. 135–139], [15, pp. 190–196].

[22] Massachusetts Institute of Technology, Department of Mathematics, Report to the Visiting Committee, March 13, 1935, Box 12: Correspondence, 1935–1939, Folder: Massachusetts Institute of Technology, Roland G. D. Richardson Papers, Brown University. On the MIT department, see [77].

geometry applied in various physical contexts, but especially in dynamics [87, p. 63]. Joining the MIT faculty as an instructor in 1908, Lipka had, by 1914, opened at MIT an applied mathematics laboratory patterned after Edmund Whittaker's in Edinburgh, published a two-volume work on *Graphical and Mechanical Computation* in 1918 [44], and risen to the rank of associate professor by 1923. His untimely death a year later at the age of only forty-one cut short what was already a vibrant career. Together with Clarence Moore, Henry Phillips, and Frank Hitchcock, Lipka and Wiener gave a decidedly applied flavor to the MIT program of the 1920s.

Similarly, various members of the mathematics department at the University of Michigan appreciated and fostered applied mathematical topics. German-born Alexander Ziwet had followed his 1880 degree in civil engineering from Karlsruhe with posts, first, at the United States Lake Survey and, then, in the computing division of the U. S. Coast and Geodetic Survey. He shifted into academe in 1888 on accepting an instructorship at Michigan and had moved through the ranks there to professor by 1904. Described as one who looked at mathematics "especially from the applied point of view", Ziwet was also a man of "high ideals in connection with engineering education" who promoted "graduate work and research" [38, pp. 181–182]. He was joined in 1895 by fresh Harvard PhD James Glover, who, although ultimately not an influential researcher, "did much to build a strong program" at Michigan in yet another applied area, actuarial mathematics [38, p. 182]. In particular, mathematical statistics entered the curriculum through this initiative when Harry Carver was appointed to an assistant professorship in 1918 [17, p. 573].

Michigan's applied offerings became more systematic in the 1920s as its mathematics curriculum further expanded to include courses in "vector analysis, hydrodynamics, elasticity, [and] celestial mechanics", and the faculty grew to accommodate both these curricular changes and the department's increasingly research-oriented ethos [38, p. 183]. In particular, the Kazan-trained specialist in the theory of relativity, George Rainich, came to Michigan in 1926 and had trained his first graduate student (and later colleague), Ruel Churchill, by 1929. Churchill ultimately became a strong proponent for mathematics applied in various physical contexts, while Rainich's third Michigan PhD, Walter Menge, added strength to the department's actuarial program.

In the 1920s, then, Michigan, like MIT, was an American node for more applied mathematical work and training. This was evidenced in the AMS's annual meetings by the repeated presence on the program of at least two Michigan-associated mathematicians: Forsyth, who although at Dartmouth in the 1920s was a 1915 PhD under Glover at Michigan, and Rainich. Forsyth lectured at least five times over the course of the decade on various aspects of financial mathematics, while Rainich spoke on his work in the three consecutive years of 1923, 1924, and 1925 and, like Struik, was a discussant at the quantum mechanics symposium.

There was also evidence within the AMS of the promotion of applied mathematics at the University of Wisconsin in Madison. In 1923 and 1924, James Henry Taylor lectured on the statistical theory of depreciation before accepting assistant professorships, first, at Lehigh University in 1925 and, then, at the University of Wisconsin a year later. Taylor had earned his PhD under Gilbert Bliss at Chicago in 1923 for a thesis that explored aspects of the mathematical theory of relativity, specifically, vector analysis in an n-dimensional Riemannian geometry [78]. He was thus well-suited to become part of the group in mathematical physics that formed at Wisconsin around Weaver, Max Mason, and Herman March. The latter, as noted, was one of the featured speakers at the symposium on the differential equations of engineering that was held as part of the AMS's annual meeting in 1929 [62, p. 150]. In particular, March directed the doctoral research of then Wisconsin instructor, Ivan Solkolnikov, in 1930. Sokolnikov, who had emigrated to the United States from Russia in the aftermath of the Russian Revolution, had received his undergraduate training at the University of Idaho before moving on for graduate work at Wisconsin. He remained on the Wisconsin faculty until 1944, producing a number of PhDs there in applied mathematics before his move to UCLA in 1946.

The 1930s witnessed the continued AMS presence of faculty and PhD students with applied interests from all three of these departments, but at least two others—at the University of Iowa and New York University—joined their ranks. At Iowa, Henry Rietz animated a robust program in mathematical statistics that included his 1931 PhD student Allen Craig. Together, they not only trained a number of mathematical statisticians throughout the 1930s but also collaborated on both the *Annals of Mathematical Statistics* founded in 1930 by Carver at Michigan and the Institute for Mathematical Statistics (IMS) begun in 1935 with the *Annals* as its official journal [36]. Mathematical statisticians, who had come together within the context of the AMS, had, by the 1930s, formed their own professional society. Still, just months after its formation, the IMS was meeting jointly with the AMS in January 1936 and, in so doing, more formally diversifying the latter's mathematical coverage [37, pp. 150 and 160]. At NYU, Richard Courant built yet another program with an applied thrust, but in the direction of mathematical physics. Former head of the Mathematics Institute in Göttingen and a proven structure-builder, Courant had managed by the 1937–1938 academic year to hire his former student, assistant, and fellow émigré, Kurt Friedrichs, as well as American James Stoker, and the two younger men had presented the early fruits of their collaborative labors, a paper on "The Nonlinear Boundary Value Problem of the Buckled Plate", at the AMS's annual meeting in Virginia in December 1938 [31, p. 205].

Before the outbreak of World War II, then, there were at least five programs in the United States where students were being trained in and research was being done on applied mathematical topics. At least one other program could be added to this list. As noted, two Gibbs Lecturers, Theodore von Kármán and Harry Bateman, taught at the California Institute of Technology, even if, owing to their West Coast home base, their physical presence and that of their students at annual meetings of the AMS was not generally feasible.[23]

As the standard historical narrative about the development of applied mathematics in the United States rightly has it, the war also spurred the creation of other programs. Most visibly, in the summer of 1941, just before what seemed like the United States' inevitable entry into World War II, the same Roland Richardson who, as AMS Secretary, had advocated as early as 1924 for the AMS to focus more tightly on applied mathematics, had launched—together with his colleagues at Brown—a twelve-week summer school of Advanced Instruction and Research in Mechanics "designed for the purpose of increasing the effectiveness of research in essential American industries" [48, p. 548]. Staffed by applied mathematicians—NYU's Friedrichs, Sokolnikov from Wisconsin, Brown's own Jacob Tamarkin as well as its recent émigré hire, Stefan Bergman—the program drew some fifty students

[23]For more on this program and especially von Kármán's role in building it, see [26].

from graduate programs in mathematics, physics, and engineering as well as from industry for the study of the mathematics of "fluid dynamics, elasticity, plasticity, aerodynamics, theory of vibrations, theory of structures, and so forth" [70, p. 422]. As Richardson had explained to von Kármán in March 1941, "Brown wishes to do its share in building up a strong program for defense" in the short term, but, as he freely acknowledged, "our hopes run beyond 1942".[24] "If we can develop along these lines from the small beginnings now planned", he added, "Brown University may be able to make a notable contribution to the building-up of applied science" in the United States. Indeed, the program was extended through the 1941–1942 academic year and ultimately throughout the war. Additional faculty members were also hired, most notably, émigré William Prager. The apparent success of their venture further emboldened Richardson and his colleagues finally "to fill" the long-perceived "gap between purely engineering journals and purely mathematical ones" with their launch in 1943 of the *Quarterly of Applied Mathematics* [28]. By 1946, when from the modest summer school a free-standing Graduate Division of Applied Mathematics had evolved, Brown had, indeed, affected "notable" changes in the American applied mathematical landscape.[25]

A closer look, moreover, at the some 150 mathematicians whose abstracts were categorized as "applied mathematics" between 1941 and 1947 reveals even more schools at which applied work was being fostered. Those mathematicians trained in the United States had earned their degrees from the programs already mentioned but also from Iowa State (under Dio Lewis Holl, a 1925 student of Arthur Lunn at Chicago), the University of Illinois (with David Bourgin, who had earned his Harvard PhD under the joint direction of George Birkhoff in mathematics and Edwin Kemble in physics), and the University of Toronto (under Synge from 1930 until his move to Ohio State in 1943), among others. They found themselves both in these and other academic settings as well as outside of academe: in the aircraft industry (Douglas, Boeing, Northrop, Curtiss-Wright, Grumman) owing largely to von Kármán's successful program at Caltech; in other industries (Eastman Kodak, General Electric, Bell Labs); and in the Federal government (the Office of Naval Research, the National Bureau of Standards), among other venues. From the 1920s through the 1940s and into the 1950s, the presence of programs in applied mathematics as well as the fruits of their labors were thus evident in the institutional setting of the AMS.

The survey of training and research in applied mathematics in the United States: 1952–1954

With the rise of Federal support for mathematics in World War II's immediate aftermath, those agencies primarily involved—the Army's Office of Ordnance Research, the Office of Naval Research, the Office of Scientific Research of the Air Force, and the National Science Foundation (created in 1950)—called on the Division of Mathematics of the National Research Council to undertake a comprehensive survey of research and training in applied mathematics in the United States. A committee was duly appointed—comprised of Hendrik Bode of Bell Labs, Courant, the University of Chicago's Marshall Stone, Abraham Taub of the University of

[24]Richardson to von Kármán, 31 March, 1941, Box 2, Folder I.37: Von Kármán, Theodore, Division of Applied Mathematics Papers. The quotation that follows is also from this letter.

[25]For more on these developments, see [50, pp. 350–360].

Illinois, and Princeton's John Tukey—and, in 1952, began its work in consultation with John Curtiss (until 1953 chief of the Applied Mathematics Division of the National Bureau of Standards in Washington, DC), Marston Morse and John von Neumann both at the Institute for Advanced Study, and mathematical physicist H. P. "Bob" Robertson of Caltech. Hermann Weyl's son, Joachim, of the Office of Naval Research, served as the committee's investigator. Two years later, this team submitted its final report, which appeared in print in 1956 [84, p. iii].

The committee went about its work with deliberation. While it waited for responses to its survey to come in, it mounted two conferences in 1953 in conjunction with regular meetings of the AMS on "training" and "special topics" in applied mathematics. The first, held at Columbia in October, was comprised of seven sessions dispersed throughout the meeting's three days. The speakers in each aimed to describe how applied mathematics was taught and incorporated in a variety of American institutional contexts—the "traditional" mathematics department, the "integrated school of applied science" like MIT, NYU's new Graduate Institute of Applied Mathematics, "government establishments", "industrial organizations"—as well as in Europe [16, pp. 21–22]. "[B]ringing together both producers and consumers of applied mathematicians and having them compare their ideas, experiences, and expectations", this conference was judged to have "significantly contributed [to] a clarification of the problems faced by the various groups who have a stake in the training of applied mathematics" [83, pp. 38 and 44, respectively]. The second conference held at Northwestern in November "was designed to present characteristic current research to a large audience of mathematicians, illustrating particularly active sectors of the front along which mathematics interacts... with other scientific disciplines" [82, p. 1]. Organized into three ninety-minute sessions of three half-hour-long papers each, and strategically interspersed among the meeting's other sessions, the first treated aspects of differential equations, one-dimensional shock wave flows, and the application of conformal mapping to hydrodynamics; the second, Boolean algebras in electric circuit design, signal and noise problems, and discrete structures and large-scale computers; and the third and final, astrophysical fluid dynamics, lattice vibrations, and the geometric structure of shock wave configurations [85, p. 60].

This instruction and consciousness-raising preceded the compilation of the results of the committee's survey at the end of 1954. Composed of twenty-five questions, it had been sent to fifty-four institutions of higher education, of which, however, only twenty-nine replied. Due to this admittedly "low percentage of returns", the decision was made to treat the responses qualitatively instead of statistically as had been originally planned [84, p. 46]. Questions covered the type of training available, the numbers and backgrounds of participating students, the programmatic requirements they had to meet and the financial support available to them, research activities and its support, and general questions such as the "needs regarding" both "the nature and extent of training" and "research in particular fields of applied mathematics" [84, p. 57].

The picture that emerged was one of the "diversification and expansion" of the mathematics curriculum in applied directions at a number of schools as well as of the growth of programs at the Universities of Illinois, Maryland, and elsewhere. Still, staffing seemed problematic, since "[o]nly those with a Doctor's degree, and among them particularly the best ones, are looking for academic" as opposed to industrial or governmental positions, and they are meeting with "only indifferent success" [84, pp. 49 and 53, respectively]. The sense seemed to be that the number of "competent men who are interested and willing to teach mathematics from an applied point of view" was "totally inadequate" and that the AMS, having failed to foster "a more catholic representation of *all* mathematical interests", was at fault [84, pp. 57 and 58 (my emphasis), respectively].

The report, however, did acknowledge that the AMS had "done its best to keep pace with recent developments", instituting the Gibbs Lectures, incorporating talks and sessions on applied mathematics into its meetings, sponsoring applied mathematics symposia [84, p. 43]. Yet, "new fields and emphases [had] developed more rapidly than the Society [had] proved capable of accommodating... within its means" [84, p. 43]. This had resulted in the formation "of a number of small but fast growing splinter societies which attract workers in the currently most active fields of applied mathematics and provide for their scientific communication needs", among them, the Society for Industrial and Applied Mathematics [84, pp. 43–44]. As the report also acknowledged, these new societies sought to do for their particular areas of applied mathematics what the IMS had done for mathematical statistics from its founding in 1935, namely, provide professional accoutrements—meetings and publications—for a targeted group of practitioners.

In the mid-1950s, this seemed to be a bad thing to Weyl and, presumably, his fellow committee members. "The next few years will probably decide whether this rapidly growing group" of independent societies "will become... an effective component in the established organizations of a greater mathematical community, or whether it will emerge as an independent scientific society", the report concluded. "And even if, in the end, events should favor the emergence of an independent organization alongside the American Mathematical Society, specifically representing the applied aspects of mathematics", it is to be hoped that "a fair measure of coherence can be preserved which the ultimate unity of our science demands" [84, p. 44].

If the "ultimate unity" of mathematics was the benchmark against which the AMS was being judged, then it is little wonder that it was purportedly viewed as having failed to meet the needs of applied mathematicians [84, p. 58]. But, was this the prevailing view? Indeed, what would "prevailing" even mean, given a survey with such a disappointingly low rate of return? Or, was it perhaps the view (the wishful thinking?) of Weyl and/or the committee as a whole or in part at a historical juncture characterized by the disciplinary and subdisciplinary delineation that had resulted, in Germany, in the formation of the *Zeitschrift für Angewandte Mathematik und Mechanik* as early as 1921 and the freestanding Gesellschaft für Angewandte Mathematik und Mechanik a year later [8, p. 69] and, in the United States, of separate journals and societies for mathematical statistics [36] and symbolic logic in the 1930s?[26] Each of these earlier initiatives had arisen through the efforts of motivated individuals—particularly Ludwig Prandtl and Richard von Mises in the case of applied mathematics in Germany and, in the cases of mathematical statistics and symbolic logic in the United States, Harry Carver and Alonzo Church, among others, respectively—who felt that their subfields had reached some

[26] The Association for Symbolic Logic and its associated *Journal of Symbolic Logic* were created in 1936 specifically to meet the needs of a subgroup within the AMS. For more on this, see [50, pp. 186–189].

sort of critical mass. They represented successful historical precedents for *grassroots* efforts as opposed to the kind of *top-down* effort an AMS intervention as suggested by Weyl's report would have reflected.

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The account presented here reconfirms that, indeed, World War II *was* a catalyst that focused a critical mass of more applied mathematical practitioners in the United States—both in and outside the context of the AMS—on the specific needs of their subfield as the standard historical narrative holds. Some, like Roland Richardson, had been stalwart AMS participants. Some, like Richard Courant, were 1930s émigrés who found a home within the AMS but who also appreciated, given their prior experiences, the need for a greater emphasis on applied mathematics *per se*. Some, like the animators of the Society for Industrial and Applied Mathematics, I. Edward Block, consulting mathematician at the Philco Corporation, and George Patterson, mathematical logician at the Burroughs Adding Machine Company, found a separate, specialized society more appropriate for their needs than the AMS, even though they numbered among the AMS's members. In this way, Block and Patterson were like Carver, Rietz, Church, and others before them.

Still, as the accounting given here of the AMS's activities throughout the 1920s, 1930s, 1940s, and into the 1950s demonstrates, the AMS had, despite its purist leanings, long recognized applied mathematics as a matter of concern. It had regularly incorporated invited addresses and special symposia on applied mathematical topics into its meetings throughout the thirty-year period. It had successfully launched new applied mathematics initiatives, like the Gibbs Lectures in the 1920s and the free-standing, postwar symposia with their accompanying publications, and had tried, if unsuccessfully, to launch others, like a journal under its auspices in the early 1930s. It had created committees specifically on applied mathematics and formally recognized such research in its various categorization schemes well before the U.S.'s entry into World War II in 1941.

It was also the case that mathematicians of more applied tastes had consistently presented their work under the AMS's aegis, attesting to *their* belief that the AMS provided a viable venue, if perhaps *faute de mieux*, for the communication of their research. Indeed, even after the founding of societies of a more applied orientation, applied mathematicians continued to participate in the AMS at the same time that they contributed to the new ventures. What the standard historical narrative thus masks is the extent to which the AMS actually served as a *foundation* for the postwar development of applied mathematics in a variety of institutional contexts.

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