UNITED STATES COURT OF APPEALS FOR THE SECOND CIRCUIT
Thurgood Marshall U.S. Courthouse 40 Foley Square, New York, NY 10007 Telephone: 212-857-8500

MOTION INFORMATION STATEMENT

Docket Number(s): 15-2801(L), 15-2805 (Con)

Caption [use short title]: NATIONAL FOOTBALL LEAGUE MANAGEMENT COUNCIL, ET AL. v. NATIONAL FOOTBALL LEAGUE PLAYERS ASSOCIATON, ET AL.

Motion for: Leave to File Brief of Professors of Physics and Engineering as Amici Curiae in Support of Counter-Claimant-Appellees

Set forth below precise, complete statement of relief sought:

Leave to File Amicus Brief Pursuant to FRAP Rule 29

MOVING PARTY: Amici Curiae

☐ Plaintiff ☐ Defendant
☐ Appellant/Petitioner ☐ Appellee/Respondent

OPPOSING PARTY: National Football League Management Council

MOVING ATTORNEY: Eric R. Delinsky

OPPOSING ATTORNEY: Paul D. Clement

[name of attorney, with firm, address, phone number and e-mail]

Moving Attorney	Opposing Attorney
Zuckerman Spaeder LLP	Bancroft PLLC
1800 M Street, N.W., Suite 1000	500 New Jersey Avenue, N.W., 7th Floor
Washington, D.C. 20036	Washington, D.C. 20001

Court-Judge/Agency appealed from: United States District Court for the Southern District of New York

Please check appropriate boxes:

Has movant notified opposing counsel (required by Local Rule 27.1):
☑ Yes ☐ No (explain):

Opposing counsel's position on motion:
☑ Unopposed ☐ Opposed ☐ Don't Know

Does opposing counsel intend to file a response:
☐ Yes ☐ No ☑ Don't Know

FOR EMERGENCY MOTIONS, MOTIONS FOR STAYS AND INJUNCTIONS PENDING APPEAL:

Has request for relief been made below? ☐ Yes ☐ No
Has this relief been previously sought in this Court? ☐ Yes ☐ No
Requested return date and explanation of emergency:

Is oral argument on motion requested? ☐ Yes ☑ No (requests for oral argument will not necessarily be granted)

Has argument date of appeal been set? ☐ Yes ☑ No If yes, enter date:

Signature of Moving Attorney: Eric R. Delinsky **Date:** May 24, 2016 Service by: ☑ CM/ECF ☐ Other [Attach proof of service]

UNITED STATES COURT OF APPEALS
FOR THE SECOND CIRCUIT

Nos. 15-2801 (L) & 15-2805 (Con)

NATIONAL FOOTBALL LEAGUE MANAGEMENT COUNCIL,

Plaintiff-Counter-Defendant-Appellant,

NATIONAL FOOTBALL LEAGUE,

Defendant-Appellant,

v.

NATONAL FOOTBALL LEAGUE PLAYERS ASSOCIATION,
ON ITS OWN AND ON BEHALF OF TOM BRADY,

Defendant-Counter-Claimant-Appellee,

TOM BRADY,

Counter-Claimant-Appellee.

UNOPPOSED MOTION OF
PROFESSORS OF PHYSICS AND ENGINEERING
FOR LEAVE TO FILE BRIEF AS *AMICI CURIAE*
IN SUPPORT OF APPELLEES' PETITION FOR PANEL REHEARING
OR REHEARING EN BANC

Pursuant to Federal Rule of Appellate Procedure 29(b), Professors John J. Leonard, Arup K. Chakraborty, Christopher E. Dames, Ryan M. Eustice, Jack Feinberg, Daniel Frey, Ahmed Ghoniem, David Goldhaber-Gordon, Douglas Hart, Anette (Peko) Hosoi, Guoquan Huang, Rebecca Kramer, Vijay Kumar, John H.

Lienhard, Joel Moore, Michael J. Naughton, Lian Shen, Gaurav S. Sukhatme, David Wallace, Amos Winter, and Maria C. Yang, by undersigned counsel, hereby move the Court for leave to file the attached brief, and addenda, as *Amici Curiae* in Support of Appellees' Petition for Panel Rehearing or Rehearing En Banc.

All parties consent to this request to file an amicus brief. In further support of this motion, *amici* state as follows:

I. Statement of Interest.

This appeal concerns an arbitration about the cause of a pressure drop in the footballs used by the New England Patriots football team prior to or during a January 18, 2015 game. Because air pressure in a football drops naturally when taken from a warm locker room to a colder playing field, the arbitration involved the application of principles of physics. SPA47-48; JA235-318.

Proposed *amici* are professors of engineering and physics. Their titles and qualifications are set forth in Addendum A of the proposed brief. They include faculty from: Massachusetts Institute of Technology; Boston College; Purdue University; Stanford University; University of California, Berkeley; University of Delaware; University of Michigan; University of Minnesota; University of Pennsylvania; and University of Southern California.

These professors have an interest in ensuring that laws of physics are applied with scientific integrity in legal proceedings. They have not sought or received any compensation in connection with the proposed brief. They submit it out of professional conviction that scientific principles be explained and put to fair use.

II. The Proposed Brief Is Desirable and Relevant.

The arbitration resulted in a finding that "the *full extent* of the decline in pressure cannot be explained by environmental, physical or other natural factors" and that part of the decline was "the result of tampering." SPA47 (emphasis added). Appellee Tom Brady was punished as a result. At issue in the petition is whether this arbitral finding "draws its essence from the collective bargaining agreement" or instead reflects "merely the arbitrator's own brand of industrial justice." Slip op. 12.

Given the overlay of science, the proposed amicus brief is desirable and relevant. It explains the scientific principles at issue in the league's ruling, the league's reliance on subjective assumptions instead of critical data in its scientific analysis, and the lack of any scientific proof in support of the ruling. It also explains how underinflated footballs – by operation of nature – are a common part of the NFL and have been for many years. This is illustrated by graphs prepared by *amici* that are attached at Addendum B to the proposed brief.

Amici respectfully submit that this scientific context is desirable, relevant and indeed necessary to a review of whether an arbitration ruling interlaced with science should be upheld in the absence of scientific proof to support it.

May 24, 2016

Respectfully submitted,

/s/ Eric R. Delinsky

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CERTIFICATE OF SERVICE

I hereby certify that, on May 24, 2016, an electronic copy of this motion was filed with the Clerk of Court using the ECF system and thereby served upon all counsel appearing in this case.

/s/ Eric R. Delinsky
Eric R. Delinsky

15-2801(L)

15-2805 (Con)

United States Court of Appeals for the Second Circuit

NATIONAL FOOTBALL LEAGUE MANAGEMENT COUNCIL,
PLAINTIFF-COUNTER-DEFENDANT-APPELLANT

AND

NATIONAL FOOTBALL LEAGUE, DEFENDANT-APPELLANT

v.

NATIONAL FOOTBALL LEAGUE PLAYERS ASSOCIATION,
ON ITS OWN BEHALF AND ON BEHALF OF TOM BRADY,
DEFENDANT-COUNTER-CLAIMANT-APPELLEE

AND

TOM BRADY, COUNTER-CLAIMANT-APPELLEE

ON APPEAL FROM THE UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF NEW YORK, NOS. 15-5916, 15-5982

BRIEF OF PROFESSORS OF PHYSICS AND ENGINEERING AS *AMICI CURIAE* IN SUPPORT OF APPELLEES' PETITION FOR PANEL REHEARING OR REHEARING EN BANC, BY

[*cover continued on next page*]

JOHN J. LEONARD, ARUP K. CHAKRABORTY, CHRISTOPHER E. DAMES, RYAN M. EUSTICE, JACK FEINBERG, DANIEL FREY, AHMED GHONIEM, DAVID GOLDHABER-GORDON, DOUGLAS HART, ANETTE (PEKO) HOSOI, GUOQUAN HUANG, REBECCA KRAMER, VIJAY KUMAR, JOHN H. LIENHARD, JOEL MOORE, MICHAEL J. NAUGHTON, LIAN SHEN, GAURAV S. SUKHATME, DAVID WALLACE, AMOS WINTER, AND MARIA C. YANG

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May 24, 2016

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INTERESTS OF *AMICI CURIAE*

Amici are professors of engineering and physics. *See* Addendum A (listing and describing background of each). They have an interest in ensuring that laws of physics are applied with scientific integrity in legal proceedings. *Amici* have sought leave to file this brief, and all parties consent to its filing.[1]

SUMMARY

Although sensationalized in the press, it was no surprise to any scientist that the Patriots' footballs lost pressure during the AFC Championship. As the league's reports recognize (JA208), so-called "deflation" happens naturally when any closed vessel, such as a football, moves from a warm environment to a cold one. This is not tampering. It is science. And it pervades the NFL. Games routinely are played with footballs that fall below the league's minimum pressure requirement.

The question in the arbitration therefore was whether there was an increment of *additional* pressure loss in the Patriots' footballs (as small as 0.14 of a psig) beyond the drop that occurred naturally.[2] The Commissioner concluded there was. But he relied on analysis that admittedly was "dependent upon assumptions" about missing data – assumptions that had a "material impact on the ultimate conclusion"

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[1] No party's counsel authored this brief in whole or in part. No party, no counsel for any party, and no person other than *amici curiae* or their counsel contributed money that was intended to fund preparation or submission of this brief. Fed. R. App. P. 29(c)(5)(A)-(C).

[2] Psig denotes pound per square inch gauge, a standard pressure measurement.

(JA250; JA108) and that if adjusted in reasonable ways, would show no additional pressure drop at all. Thus his ruling was not based on scientific proof, but rather on scientifically-worded surmise. Indeed there is *no* scientific proof of wrongdoing.

As scientists, we submit that this is the context in which the Commissioner's ruling must be reviewed. This context appears missing from the majority opinion. *See* Slip op. 5. It strikes us as scientifically unsound to base a punitive ruling on a supposed increment of a few tenths of a psig, when assumptions are used to determine that such an increment even exists. Courts should not be powerless to consider the absence of scientific proof when a proceeding is so interlaced with laws of science. We support the petition for rehearing.

ARGUMENT

I. Footballs lose pressure naturally in cold weather.

The NFL requires game balls to be set, pre-game, from 12.5 to 13.5 psig. But as a matter of physics, when a vessel of air – such as a football – moves from a warm environment to a colder one, its pressure decreases. Pressure is defined as force per unit area. As the temperature of a fixed-volume vessel of gas is reduced, the average velocity of the molecules inside the vessel decreases, resulting in a proportional decrease in the magnitude of the force that the molecules of gas exert on the vessel's walls.[3] Scientists call this proportionality the Ideal Gas Law. It is natural, inevitable, and not subject to debate. The league itself acknowledges that a

[3] Car tires, for instance, lose around 1.0 psig for every 10 degree temperature drop.

pressure drop is a "natural result of footballs moving from a relatively warm environment such as a locker room to a colder environment such as a playing field" and is "consistent with basic scientific principles." JA104; JA208.

While the league understands this now, it apparently did not know before this case that footballs lose pressure naturally. JA1007-08. It announced its investigation seemingly unaware of the Ideal Gas Law or its impact.

II. There is no scientific proof of tampering.

The Ideal Gas Law resulted in a significant reduction of pressure in the Patriots' footballs. This drop occurred naturally. The league now recognizes this. Its own reports state that the Ideal Gas Law accounted for a loss of as much as 1.18 psig (a reduction from 12.5 to 11.32 psig). *See* JA208; JA290.

The league's accusation against Mr. Brady therefore was *not* that he was responsible for all or even most of the pressure loss. It was that he was responsible for an increment of additional pressure loss beyond that which occurred naturally. The league, again, acknowledges this. JA104 (pressure loss cannot be "explained *completely* by basic scientific principles"); SPA45 ("the deflation ... cannot be *fully* explained by environmental factors or scientific principles") (emphasis added).

Strikingly, the Commissioner does not identify the size of this additional increment of pressure loss that he attributes to Mr. Brady. Obscured in one of the league's reports, however, is an analysis that indicates that it was as tiny as 0.14 of a psig and no larger than 0.53 psig. JA308-09.[4] To us as scientists, an increment of pressure loss as tiny as 0.14 psig is too small to constitute proof of tampering. It is well within any reasonable margin of error, based on our assessment of the league's measurements. JA270-78.[5]

The very existence of *any* increment, moreover, was divined through assumption. The data necessary for any bona fide scientific analysis was never collected. The league, yet again, recognizes this. It states that its analysis is "dependent upon assumptions and information that is not certain." JA250. These assumptions and uncertainties relate to critical variables necessary to determine the nature of the pressure loss. Indeed, the league states that "varying the applicable assumptions can have a material impact on the ultimate conclusions." JA108.[6]

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[4] Two gauges were available to test the footballs pre-game. There is no record of which one was used. If the "logo" gauge was used, the league states the pressure of the footballs at halftime should have been no lower than 11.35 psig. JA309. The actual footballs under this gauge, per the league's "master gauge" analysis, were on average 11.21 psig. JA308. This leaves an increment of 0.14 psig. If the "non-logo" gauge was used, the league states the pressure of the footballs at halftime should have been as high as 11.62 psig. *Id*. The actual footballs under this gauge, per the league's "master gauge" analysis, were on average 11.09 psig. *Id*. This leaves a high-end increment, in the league's view, of 0.53 psig.

[5] There is imprecision in inexpensive gauges, and the halftime testing "was not performed…under ideal circumstances for forensic data collection." JA165 n.42.

[6] The league states that it has identified no "credible environmental or physical factors that completely accounts for the additional loss in air pressure." JA250. But this statement itself contains qualifications like "based on all of the information provided to us" and "within the range of game characteristics most likely to have

For example, in asserting that the additional increment could have been as low as 0.14 psig, the league assumed a locker room temperature of 67 ºF when the footballs were tested pre-game. JA308-09. But elsewhere in its analysis, it assumed that the temperature, in the same room at the same time, was 71 ºF. JA307. It simply switched the assumption. Had the league used its 71 degree assumption consistently, then the 0.14 psig increment changes to -0.06 psig.[7] The alleged deflation becomes non-existent.

Likewise, in asserting that the increment could be as high as 0.53 psig, the league assumed the referee used a particular gauge. The referee told the league, however, that his "best recollection" was that he used a different gauge. JA147. That gauge shows smaller increments of additional pressure loss. JA308-09.[8]

If these two assumptions were changed to be consistent with the temperature assumption made elsewhere and with the information provided by the referee, the increment of pressure loss beyond the drop which occurred naturally is as low as

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occurred." *Id.* The report later states that these "parameters" of what was likely were set by league counsel. JA297.

[7] Due to the Ideal Gas Law, a starting temperature of 4 degrees higher in the locker room leads to a further reduction in the on-field pressure by 0.20 psig.

[8] The assertion that the increment could be as high as 0.53 psig relies on many other assumptions too. For instance, while acknowledging that wetness causes greater pressure drops (JA293), it assumes the impact of the wetness on the field can be replicated by spraying footballs "occasionally" with a "household spray bottle" in a laboratory. JA306. Likewise, it assumes that the officials let the balls warm back up in the locker room for four minutes before testing them. JA308.

zero. At most it would be a mere 0.13 psig (well within the margin of error), even before addressing other issues in the league's analysis. Had the league made these two different assumptions alone, the results would have vindicated Mr. Brady.

We provide this analysis to explain what the "science" used by the league is not. It most assuredly is not scientific *proof* that the Patriots' footballs lost pressure beyond the drop caused naturally by the Ideal Gas Law. Rather it is a malleable and subjective analysis based on a host of assumptions – selected to some degree by league counsel (JA297) – that if varied in any number of reasonable ways, lead to the conclusion that all deflation occurred naturally. There is no scientific proof of tampering.

III. "Deflated" footballs are a regular feature of the NFL.

Indeed for decades, NFL games have been routinely played with underinflated balls due to the Ideal Gas Law. For any game where the field temperature is 20 or more degrees lower than the locker room where the footballs were tested, footballs will naturally "deflate" below the league minimum of 12.5 psig. If footballs initially are set lower than the 13.5 psig maximum, as the Patriots' footballs were, even much smaller temperature differences will result in natural deflation below 12.5 psig.

Amici have obtained data on the field temperatures for over 10,000 outdoor NFL games dating back to 1960. If one assumes a 70 degree locker room and 13.0

psig balls and then applies the reported game temperatures, approximately 61% of the games would have featured footballs that descended below the permitted range. *See* Addendum B. Assuming that footballs were set initially at the lower end of the permitted range where the Patriots' footballs were set (12.5 psig), approximately 82% of the games would have featured footballs that descended below the permitted range. *Id.* Even assuming footballs were set initially at the high end of the range (13.5 psig), approximately 38% of the games still would have featured footballs that descended below the permitted range. *Id.*

Not surprisingly in light of physics, in the game at issue here, *both* teams' footballs were underinflated by halftime. Indeed, the league's own graphs show that the Colts' footballs, which the referee stated were set pre-game at 13.0 psig, would have measured approximately 11.8 psig at the time they left the field (before they heated back up in the locker room and were then measured). *See* JA300-01; JA303; JA305; JA310-11. Due to the Ideal Gas Law, they fell below the league's minimum requirement of 12.5 psig even though they initially were set above it.

League rules permit this. While they require the pressure of the footballs to be tested *before* the game, they require no testing or re-inflation *during* the game – even though it is inevitable under the Ideal Gas Law that the pressure of the footballs will drop well below the league minimum during cold weather games. JA127-28. The point is not that "tampering" is allowed. It is that a reduction of pressure in footballs, below the league minimum, occurs naturally and regularly in the NFL without any correction by the league. Any review of the league's ruling must be framed by these scientific facts.

CONCLUSION

As professors, we cannot fathom how it is permissible to impose punishment for the possibility of a negligible increment of pressure loss, when underinflated footballs are common to NFL games, when laws of physics cause much larger pressure drops, and when the very possibility of an additional increment of pressure loss was generated from assumptions of the league's choosing rather than data. In the name of science, we support the petition for rehearing.

May 24, 2016

Respectfully submitted,

/s/ Eric R. Delinsky

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CERTIFICATE OF COMPLIANCE

I hereby certify the foregoing BRIEF OF PROFESSORS OF PHYSICS AND ENGINEERING AS *AMICI CURIAE* IN SUPPORT OF APPELLEES, complies with the typeface requirements of Federal Rule of Appellate Procedure 32(a)(5) and the type style requirements of Federal Rule of Appellate Procedure 32(a)(6) because this brief has been prepared in a proportionally spaced typeface using Microsoft Word 2007 in 14-point Times New Roman font. Further, this amicus brief complies with the limitation on length set by Federal Rules of Appellate Procedure 29(d) and 35(b)(2).

May 24, 2016

/s/ Eric R. Delinsky
Eric R. Delinsky

CERTIFICATE OF SERVICE

I hereby certify that, on May 24, 2016, I caused an electronic copy of the Brief of Professors of Physics and Engineering as *Amici Curiae* to be filed with the Clerk of Court using the ECF system, and thereby served upon all counsel appearing in this case.

/s/ Eric R. Delinsky
Eric R. Delinsky

ADDENDUM A

LIST OF *AMICI*

John J. Leonard is the Samuel C. Collins Professor in the Department of Mechanical Engineering at Massachusetts Institute of Technology. He holds the degrees of B.S.E.E. in Electrical Engineering and Science from the University of Pennsylvania and D.Phil. in Engineering Science from the University of Oxford. He is a Fellow of the Institute for Electrical and Electronics Engineers. Dr. Leonard teaches subjects in Measurement & Instrumentation, Electronics, and Robotics at MIT.

Arup K. Chakraborty is the Robert T. Haslam Professor of Chemical Engineering, Physics, Chemistry, and Biological Engineering at Massachusetts Institute of Technology. He is also the Founding Director of MIT's Institute for Medical Engineering & Science. His current research lies at the intersection of statistical physics and immunology. He teaches subjects such as statistical mechanics and thermodynamics, fluid mechanics, and physical concepts in immunology. Dr. Chakraborty was elected to the National Academy of Sciences and the National Academy of Engineering for completely different bodies of work. He is also a Fellow of the American Academy of Arts & Sciences and the American Association for the Advancement of Science.

Christopher E. Dames is an Associate Professor in the Department of Mechanical Engineering at the University of California, Berkeley. He holds the degrees of B.S. and M.S. in Mechanical Engineering from the University of California, Berkeley, and Ph.D. in Mechanical Engineering from Massachusetts Institute of Technology. He has been honored with an NSF CAREER Award, DARPA Young Faculty Award, and Viskanta Fellowship and heat transfer lectureship at Purdue University. His teaching and research expertise is in thermodynamics and heat transfer.

Ryan M. Eustice is an Associate Professor in the Department of Naval Architecture and Marine Engineering at the University of Michigan. He holds joint appointments in the Department of Electrical Engineering and Computer Science, and the Department of Mechanical Engineering. He holds the degrees of B.S. in Mechanical Engineering from Michigan State University and Ph.D. in Ocean Engineering from the MIT/WHOI Joint Program. Professor Eustice is Director of the Perceptual Robotics Laboratory and he is the recipient of an NSF CAREER Award and an ONR Young Investigator Award. He teaches subjects in marine hydrodynamics, marine dynamics, and robotics.

Jack Feinberg is a Professor of Physics and Astronomy at the University of Southern California. He holds the degrees of B.A. in Physics from Columbia University and Ph.D. in Physics from the University of California, Berkeley. Dr. Feinberg has authored over 90 publications and holds 13 patents. He has received the Discover Award for Technological Innovation in the Field of Sight and is a Fellow of the Optical Society of America.

Daniel Frey is a Professor of Mechanical Engineering at Massachusetts Institute of Technology. He holds the degrees of B.S. in Aeronautical Engineering from Rensselaer Polytechnic Institute, M.S. in Mechanical Engineering from University of Colorado, and Ph.D. in Mechanical Engineering from MIT. He is the recipient of an NSF CAREER Award, R&D 100 Awards, Best Paper Awards from ASME, INCOSE, IEEE, and ASEE, and he is an ASME Fellow. Dr. Frey teaches subjects in Statistics, Numerical Computation, and Mechanical Design at MIT.

Ahmed Ghoniem is the Ronald C. Crane (1972) Professor in the Department of Mechanical Engineering at Massachusetts Institute of Technology. He also is the Director of the Center for Energy and Propulsion Research and Director of the Reacting Gas Dynamics Laboratory at MIT. He holds the degrees of B.Sc. and M.Sc. in Mechanical Engineering from Cairo University, Egypt and Ph.D. in Mechanical Engineering from University of California, Berkeley. Professor Ghoniem is a Fellow of the American Society of Mechanical Engineers (ASME) and is a recipient of the ASME James Harry Potter Gold Medal, which recognizes eminent achievement or distinguished service in the science of thermodynamics and its application in mechanical engineering.

David Goldhaber-Gordon is a Professor of Physics at Stanford University. He holds the degrees of A.B. in Physics from Harvard University, A.M. in History of Science from Harvard University, and Ph.D. in Physics from Massachusetts Institute of Technology. Dr. Goldhaber-Gordon has been the recipient of several fellowships and awards, including the Packard Fellowship, the George E. Valley Prize from the American Physical Society, the McMillan Award from the University of Illinois, and an Award for Initiatives in Research from the National Academy of Sciences.

Douglas Hart is the Skolkovo Foundation Professor of Mechanical Engineering in the Department of Mechanical Engineering at Massachusetts Institute of Technology. He holds the degrees of B.Sc. from the University of Illinois, Urbana-Champaign, M.Sc. from MIT, and Ph.D. from the California Institute of Technology. Dr. Hart teaches subjects in engineering systems design and development, as well as imaging ventures and fabrication.

Anette (Peko) Hosoi is a Professor of Mechanical Engineering and Associate Department Head for Education in the Department of Mechanical Engineering at Massachusetts Institute of Technology. She holds the degrees of B.A. from Princeton University and M.Sc. and Ph.D. from the University of Chicago. She is the founder and director of STE@M (Sports Technology and Education @ MIT) which is dedicated to building an interconnected community of faculty, students, industry partners, and athletes who are passionate about tackling challenges that lie at the intersection of engineering and sports. Dr. Hosoi is a Fellow of the American Physical Society.

Guoquan Huang is an Assistant Professor of Mechanical Engineering, Electrical and Computer Engineering at the University of Delaware. He holds the degrees of B.Eng. from the University of Science and Technology Beijing, China, M.Sc. from the University of Minnesota, and a Ph.D. from the University of Minnesota. Dr. Huang received the University of Delaware Research Foundation Award in 2015 and leads the University of Delaware Robot Perception and Navigation Group.

Rebecca Kramer is an Assistant Professor of Mechanical Engineering at Purdue University. She holds the degrees of B.S. from Johns Hopkins University, M.S. from the University of California, Berkeley, and Ph.D. from Harvard University. She is the recipient of the NSF CAREER Award, the NASA Early Career Faculty Award, the AFOSR Young Investigator Award, and was named to the 2015 Forbes 30 Under 30 list. Dr. Kramer's research is in the area of soft robotics and she teaches mechanical design at Purdue.

Vijay Kumar is the Nemirovsky Family Dean of the School of Engineering and Applied Science and a Professor of Mechanical Engineering and Applied Mechanics, Computer and Information Science, and Electrical and Systems Engineering at the University of Pennsylvania. He holds a Ph.D. from The Ohio State University. Dr. Kumar has been elected to the National Academy of Engineering and is a Fellow of both the American Society of Mechanical Engineers and the Institute for Electrical and Electronics Engineers.

John H. Lienhard V is the Abdul Latif Jameel Professor in the Department of Mechanical Engineering at Massachusetts Institute of Technology. He holds B.S.E. and M.S.E. degrees in Thermal Engineering from the University of California, Los Angeles and a Ph.D. in Engineering Science from the University of California, San Diego. He is a Fellow of the American Society of Mechanical Engineers (ASME) and a recipient of the ASME Heat Transfer Memorial Award, the ASME Globalization Medal, the NSF Presidential Young Investigator Award, and many best paper awards. He has taught measurement and thermal science at MIT for nearly 30 years, and he is the author of widely used textbooks on measurement and instrumentation and on heat transfer.

Joel Moore is a Professor of Physics at the University of California, Berkeley. He holds the degrees of A.B. in Physics from Princeton University, and Ph.D. from Massachusetts Institute of Technology. Dr. Moore has received several fellowships, including an American Physical Society fellowship, and authored more than 100 research articles in theoretical condensed matter physics. His research is currently supported by the National Science Foundation, the Department of Energy, the Department of Defense, and the Simons and Moore Foundation.

Michael J. Naughton is the Evelyn J. and Robert A. Ferris Professor in and Chairman of the Department of Physics at Boston College. He holds the degrees of B.S. in Physics from St. John Fisher College and Ph.D. from Boston University, and did postdoctoral work at the University of Pennsylvania. Dr. Naughton is a recipient of an NSF Young Investigator Award and is a Fellow of the American Physical Society, with over 200 publications and 20 patents in condensed matter physics and micro/nanotechnologies. His research has been funded by the National Science Foundation, the Department of Energy, the National Institutes of Health, and the W.M. Keck Foundation.

Lian Shen is the Benjamin Mayhugh Associate Professor in the Department of Mechanical Engineering at University of Minnesota. He holds the degrees of B.S. in Mechanical Engineering from the University of Science and Technology of China and Sc.D. in Fluid Mechanics from Massachusetts Institute of Technology. Professor Shen is the recipient of an ONR Young Investigator Award. He is the Associate Director for Research in the Saint Anthony Falls Laboratory, a multidisciplinary fluid mechanics institute at the University of Minnesota. Dr. Shen teaches courses in fluid dynamics and thermodynamics.

Gaurav S. Sukhatme is Professor of Computer Science in the Viterbi School of Engineering, with a joint appointment in Electrical Engineering, at the University of Southern California. He received his undergraduate education at IIT Bombay in Computer Science and Engineering, and he holds the degrees of M.S. and Ph.D. in Computer Science from USC. Dr. Sukhatme is a Fellow of the Institute for Electrical and Electronics Engineers and a recipient of the NSF CAREER award and the Okawa Foundation research award.

David Wallace is a Professor of Mechanical Engineering at Massachusetts Institute of Technology. He earned his Bachelor of Engineering and Bachelor of Industrial Design degrees at Carleton University in Ottawa, Canada, and received his S.M. and Ph.D. degrees in Mechanical Engineering at MIT. He has won numerous teaching awards at MIT and was named a MacVicar Faculty Fellow, MIT's highest teaching honor.

Amos Winter is Assistant Professor in the Department of Mechanical Engineering at Massachusetts Institute of Technology. He holds the degrees of B.S. in Mechanical Engineering from Tufts University, S.M. in Mechanical Engineering from MIT, and Ph.D. in Mechanical Engineering from MIT. Dr. Winter is the founder and director of the Global Engineering and Research Lab at MIT.

Maria C. Yang is Associate Professor in the Department of Mechanical Engineering at Massachusetts Institute of Technology. She holds the degrees of S.B. from MIT, M.S. from Stanford University, and Ph.D. from Stanford University. Dr. Yang is a Fellow of the American Society of Mechanical Engineers and a recipient of the NSF CAREER award. She is the founder and director of the Ideation Lab at MIT.

ADDENDUM B

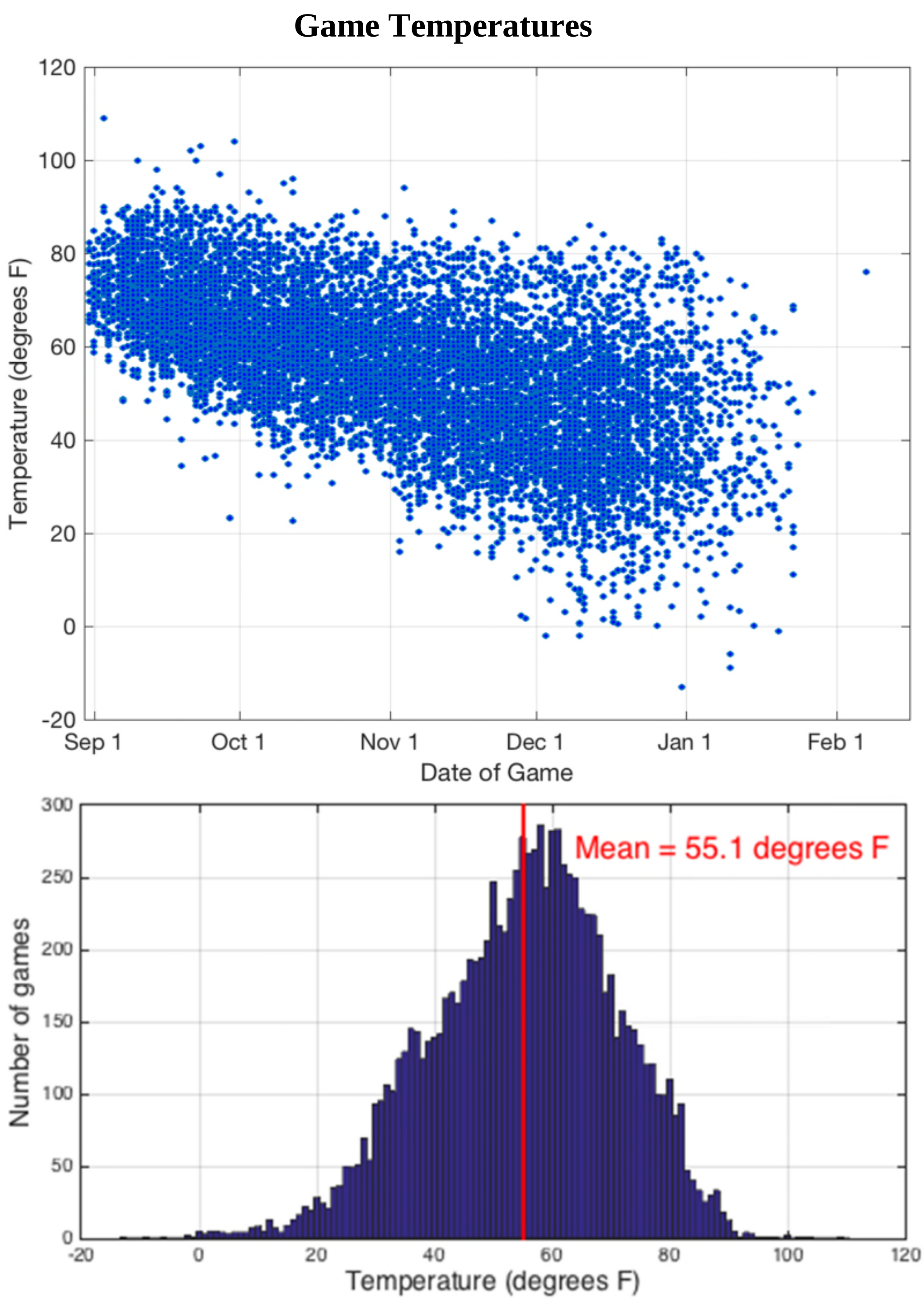

Figure 1. Scatter plot (top) and histogram (bottom) for the game temperatures of 10,307 NFL games played outdoors from 1960 to 2016. Games in stadiums with a dome or retractable roof are omitted.

Source: **http://www.pro-football-reference.com/play-index/tgl_finder.cgi**

Assuming 12.5 psig Starting Pressure

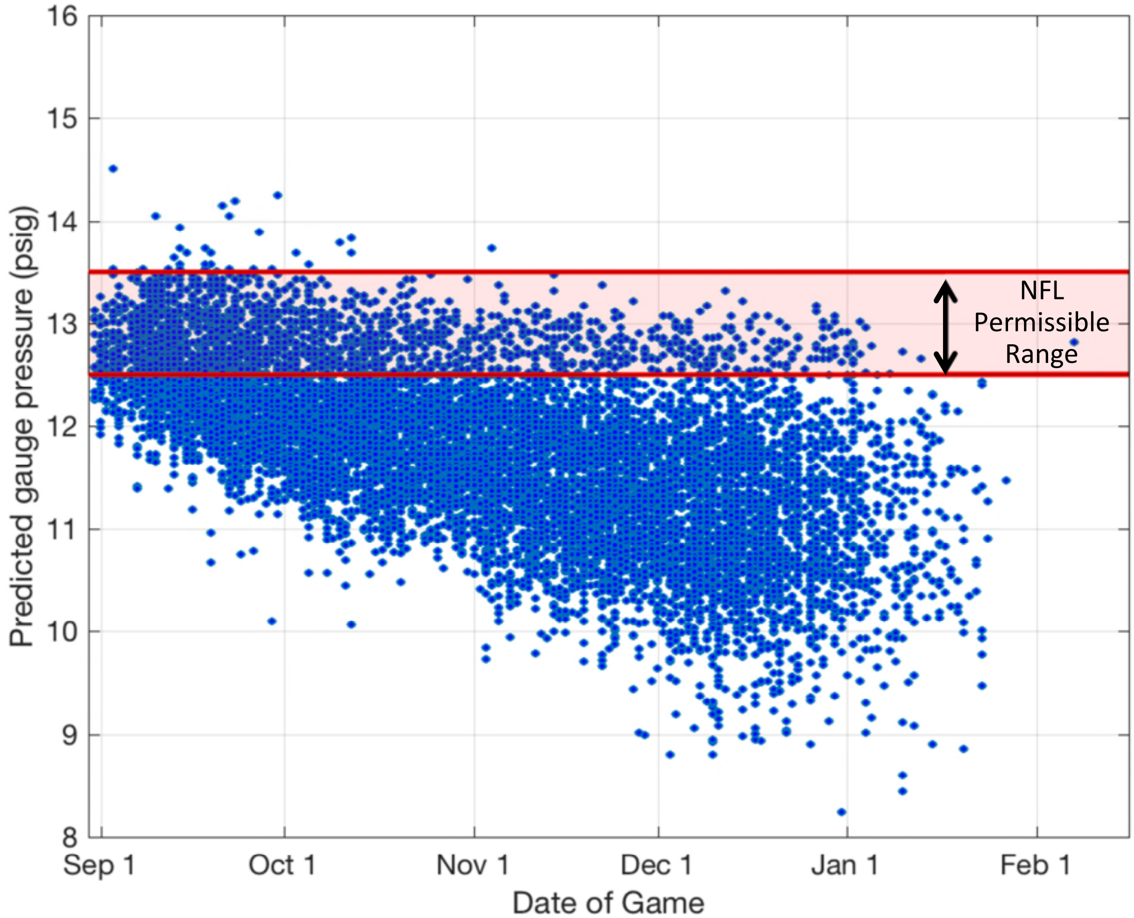

Figure 2. Predicted pressure levels of footballs using the historical game temperatures plotted in Figure 1, assuming pre-game inflation to 12.5 psig in a 70 degree Fahrenheit locker room. The shaded region indicates the 12.5 psig to 13.5 psig pre-game range required by the NFL. 82.1% of the games have a predicted on-field ball pressure below 12.5 psig, 17.6% of the games have a predicted on-field pressure within the 12.5 psig to 13.5 psig range, and 0.3% of the games have a predicted on-field ball pressure above 13.5 psig.

Note: psig denotes “pounds per square inch gauge,” indicating a pressure measured relative to atmospheric pressure. Atmospheric pressure is assumed to be 14.7 pounds per square inch for these computations.

Assuming 13.0 psig Starting Pressure

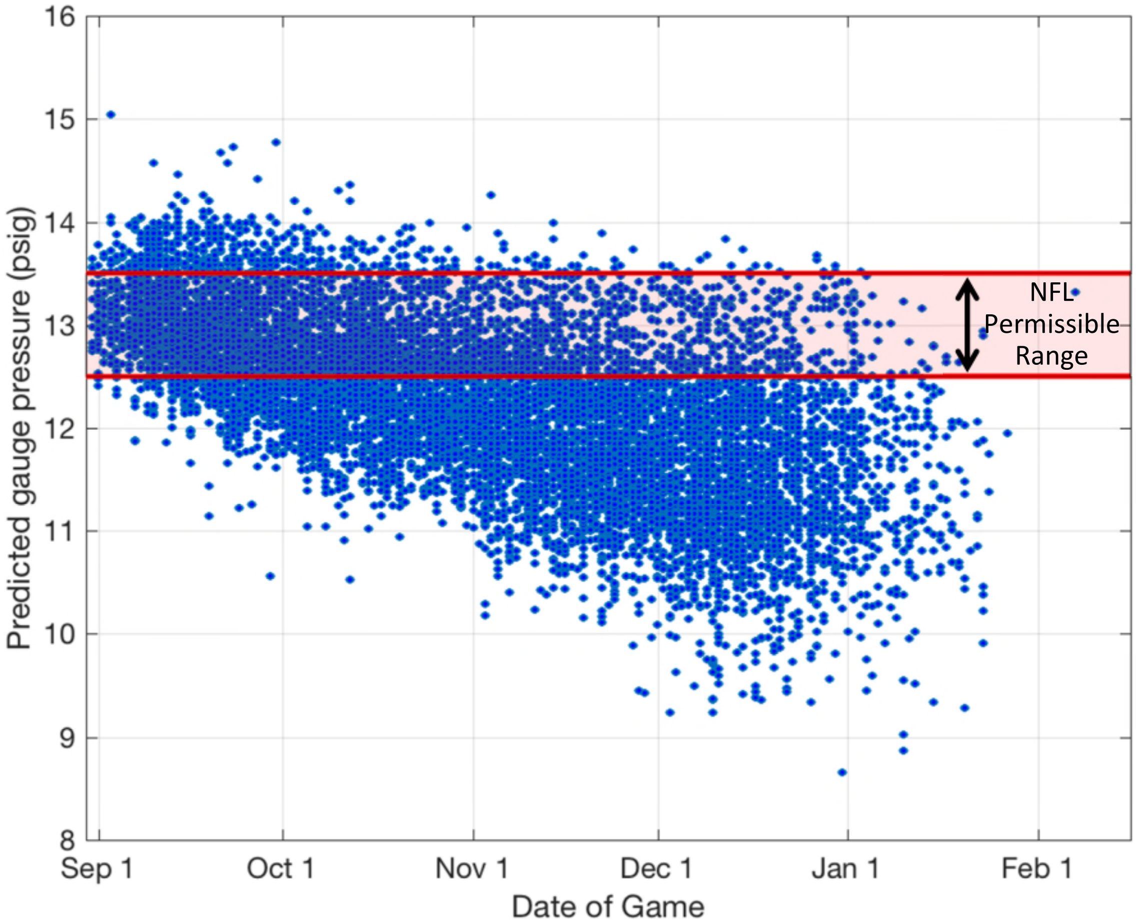

Figure 3: Predicted pressure levels of footballs using the historical game temperatures plotted in Figure 1, assuming pre-game inflation to 13.0 psig in a 70 degree Fahrenheit locker room. 61.0% of the games have a predicted on-field ball pressure below 12.5 psig, 33.7% of the games have a predicted on-field pressure within the 12.5 psig to 13.5 psig range, and 5.3% of the games have a predicted on-field ball pressure above 13.5 psig.

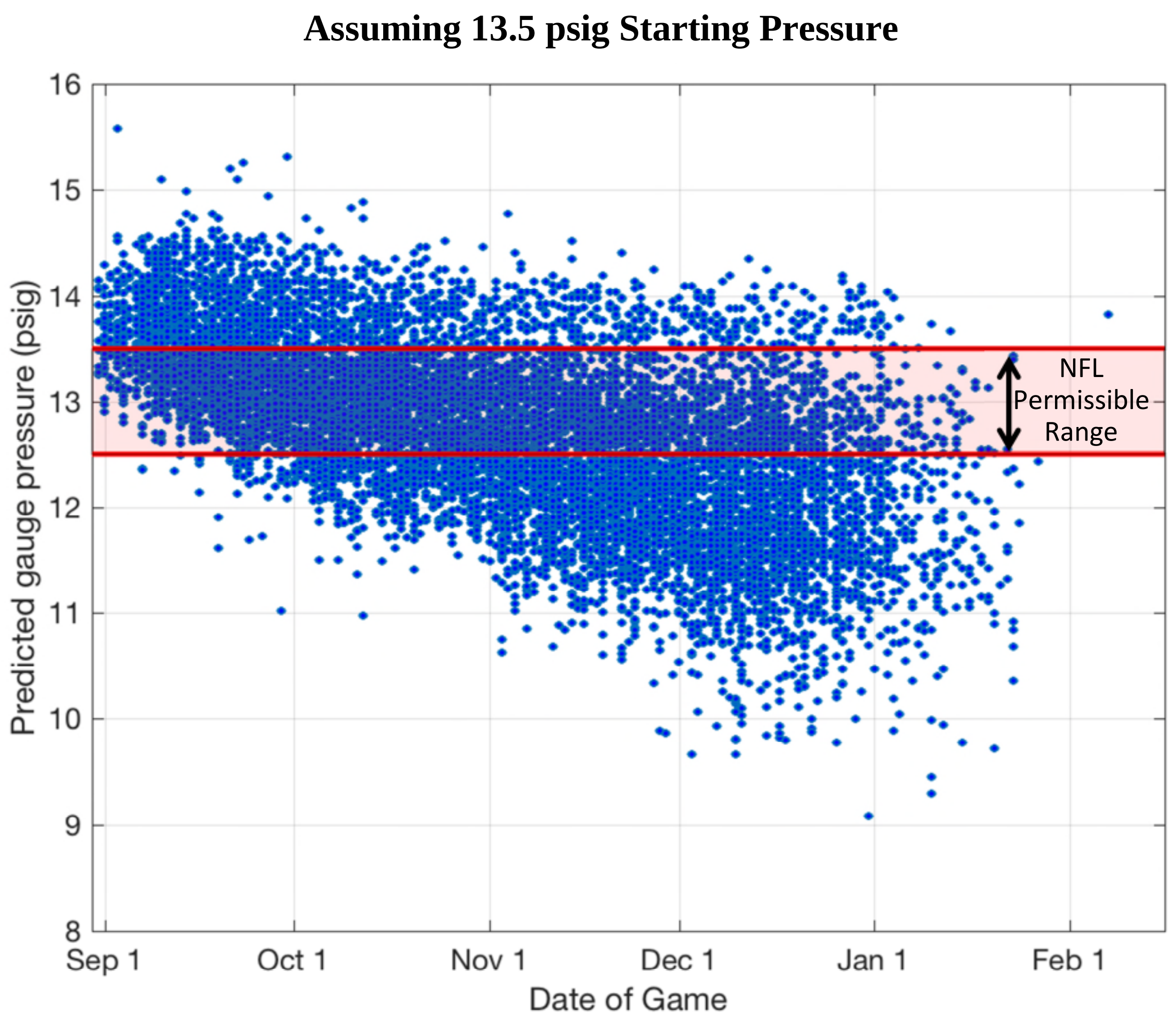

Figure 4: Predicted pressure levels of footballs using the historical game temperatures plotted in Figure 1, assuming pre-game inflation to 13.5 psig in a 70 degree Fahrenheit locker room. 38.2% of the games have a predicted on-field ball pressure below 12.5 psig, 44.7% of the games have a predicted on-field pressure within the 12.5 psig to 13.5 psig range, and 17.1% of the games have a predicted on-field ball pressure above 13.5 psig.