UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

REVELYST SALES LLC
Petitioner

v.

BRAINGUARD TECHNOLOGIES INC.
Patent Owner

IPR2025-01032
U.S. Patent No. 9,414,635

DECLARATION OF DR. STEFAN M. DUMA REGARDING CLAIMS 1-4, 6, 8-12, 14 AND 16-20 OF U.S. PATENT NO. 9,414,635

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I, Stefan M. Duma, declare as follows:

I. INTRODUCTION

1. My name is Stefan M. Duma.

2. I am making this declaration at the request of Revelyst Sales LLC ("Petitioner") as an independent expert consultant in this proceeding before the United States Patent and Trademark Office and to provide testimony pertinent to Petitioner's Petition for *Inter Partes* Review of U.S. Patent No. 9,414,635 (the "'635 Patent"). I understand that Petitioner is challenging claims 1-4, 6, 8-12, 14 and 16-20 of the '635 Patent.

II. QUALIFICATIONS AND EXPERIENCE

3. I have been studying impact injury and safety design for almost 30 years. My qualifications for forming the opinions set forth in this declaration are summarized below. My curriculum vitae ("CV"), which describes my education, experience, professional activities, and lists, among other things, my publications and patents, is attached as Appendix A.

4. I received a Bachelor of Science in Mechanical Engineering (in 1995) from the University of Tennessee, Knoxville, a Master of Science ("M.S.") in Industrial Engineering (in 1996) from the University of Cincinnati, and a Doctor of Philosophy ("Ph.D.") in Mechanical Engineering (in 2000) from the University of Virginia. While a graduate student, I was a Graduate Fellow of the National Institute

for Occupational Safety and Health, the U.S. federal agency responsible for conducting research and making recommendations for the prevention of work-related injury, illness, disability, and death.

5. From 2000-2009 I was Assistant Professor, Associate Professor, then Professor, Mechanical Engineering, at Virginia Polytechnic Institute and State University ("Virginia Tech"), when I was made the Harry C. Wyatt Professor of Engineering at Virginia Tech, which is my present position in addition to serving as Affiliate Faculty of the School of Neuroscience since 2017, Executive Director of the Institute of Critical Technology and Applied Science since 2018, University Distinguished Professor since 2022, and Interim Department Head, Biomedical Engineering and Mechanics since 2023, all at Virginia Tech. I was also the Founding Director of the Center for Injury Biomechanics at Virginia Tech and Wake Forest University from 2003 to 2009, the Founding Director of the Helmet Lab and the Virginia Tech Helmet Ratings Program from 2009 to 2016, and the Director of the Adaptive Brain and Behavior Destination Areas at Virginia Tech from 2016 to 2021. The Virginia Tech Helmet Ratings program is the largest helmet evaluation program in the world and currently publishes helmet ratings for varsity football, youth football, flag football, hockey, bicycle, equestrian, soccer, snow sport, whitewater polo, and helmet shell add-ons. I also served as Director of the School

of Biomedical Engineering and Sciences at Virginia Tech from 2009 to 2016, and was Editor in Chief of the Annals of Biomedical Engineering (flagship journal of the Biomedical Engineering Society) from 2017 through 2024.

6. My primary research interest is impact injury and safety design, including especially injury biomechanics and protective equipment. I've authored or co-authored over 567 academic publications including 203 refereed journal articles, four books, and three book chapters. My publications are described in detail in my CV (Appendix A).

7. In addition to my research, I am a member of several relevant professional societies, including, among others, the National Neurotrauma Society (since 2017), the Biomedical Engineering Society (since 2009), the American Institute for Medical and Biological Engineering (since 2009), and the American Society of Biomechanics (since 1998). I have also supervised 27 M.S. and eight Ph.D. students.

8. I have taught numerous relevant courses at Virginia Tech, including, among others, Impact Biomechanics (a course I developed), Injury Physiology (another course I developed), Mechanical Design, and two Senior Design courses covering helmet design. More recently I designed, developed and taught two new classes entitled BMES 2004 Concussion Perspectives and another new class BMES

3004 Helmet Design. These two classes have become two of the most popular courses at Virginia Tech with over 5,000 students have taken them. I authored two textbooks to support these classes, Concussion Perspectives and the second entitled Helmet Design, both published by Kendall Hunt Publishers.

9. My research on concussions and helmet design has been recognized with numerous awards including my appointment as University Distinguished Professor, the highest rank of faculty at Virginia Tech. In addition, I have been appointed Fellow status by the Biomedical Engineering Society for my research advancing concussion research and helmet design across all sports.

10. I am being compensated for my work on this matter at my standard hourly consulting rate of $400 per hour, but my opinions are based on my own views and understanding of the prior art, the knowledge of a person of ordinary skill in the art, and the patented technology. My compensation is not dependent on and in no way affects the substance of my statements, opinions, or conclusions in this Declaration nor is it dependent on any testimony I give or on the outcome of this proceeding.

11. I have no financial interest in Petitioner or Patent Owner. I similarly have no financial interest in the ’635 Patent and have had no contact with the named inventors of the ’635 Patent.

III. LEGAL PRINCIPLES

12. I am not an attorney. For the purposes of this declaration, I have been informed about certain aspects of the law that are relevant to my opinions. My understanding of the law was provided to me by Petitioner's attorneys.

A. Scope of Opinion

13. I have been informed and understand that the petitioner in an *inter partes* review may request cancellation of claims as unpatentable only on grounds that such claims are anticipated or would have been obvious to a person of ordinary skill in the art at the time of the purported invention, and only on the basis of prior art consisting of patents or printed publications. My opinions in this matter address only such grounds.

B. Anticipation

14. I have been informed by counsel that a patent claim is anticipated and therefore unpatentable if each element of that claim is present, either expressly or inherently, in a single prior art reference.

15. I understand that, to anticipate, the reference must not only disclose all elements of the claim within the four corners of the document, but must also disclose those elements arranged as in the claim. I understand that, where the reference discloses elements in different locations in the disclosure, the reference must be

sufficiently clear in disclosing the combinability of those elements such that a POSA would at once envisage the claimed combination.

16. I understand that an anticipating reference must be enabling; that is, the disclosure in the assertedly anticipating reference must be adequate such that a POSA can practice the subject matter based on the reference without undue experimentation.

C. Obviousness

17. I understand that a claim is unpatentable if it would have been obvious to a person of ordinary skill in the art at the time the alleged invention was made. I understand that a claim could have been obvious based on the teachings or suggestions of a single prior art reference or from a combination of two or more prior art references. I understand that an obviousness analysis requires an understanding of the scope and content of the prior art, any differences between the alleged invention and the prior art, and the level of ordinary skill in evaluating the pertinent art.

18. I further understand that a claim would have been obvious if it unites old elements with no change to their respective functions, involves choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success, or alters prior art by mere substitution of one element for another known in

the field, and that combination yields predictable results. Also, I understand that obviousness does not require physical combination/bodily incorporation, but rather consideration of what the combined teachings would have suggested to persons of ordinary skill in the art at the time of the alleged invention.

19. In connection with obviousness, I have been informed that there must have been some reason or motivation that would have led a person of ordinary skill in the art to combine or modify the relevant teachings in the prior art to obtain the claimed invention, and one of ordinary skill in the art must have had a reasonable expectation of success in doing so.

20. While it may be helpful to identify a reason for a combination, I understand that there is no rigid requirement of finding an express teaching, suggestion, or motivation to combine within the references. If a person of ordinary skill in the art can implement a predictable variation, obviousness likely bars its patentability. For the same reason, if a technique has been used to improve one device and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique would have been obvious. I understand that a claim would have been obvious if a person of ordinary skill in the art would have had reason to combine multiple prior art references or add missing features to reproduce the alleged invention recited in the claims.

21. In sum, I understand that a determination of whether a claim would have been obvious is based upon a variety of considerations, including, among others:

- whether the teachings of the prior art references disclose known concepts combined in familiar ways, which, when combined, would yield predictable results;
- whether a person having ordinary skill in the art could implement a predictable variation, and would see the benefit of doing so;
- whether the claimed elements represent one of a limited number of known design choices, and would have a reasonable expectation of success by those skilled in the art;
- whether a person having ordinary skill would have recognized a reason to combine known elements in the manner described in the claim;
- whether there is some teaching or suggestion in the prior art to make the modification or combination of elements claimed in the patent; and
- whether the alleged invention applies a known technique that had been used to improve a similar device or method in a similar way.

22. I also understand that in considering obviousness, it is important not to determine obviousness using the benefit of hindsight derived from the patent being considered. I also understand that one of ordinary skill in the art has ordinary creativity, and is not an automaton.

23. I further understand that certain factors, commonly referred to as secondary considerations, may support or rebut the obviousness of a claim. I also understand that secondary considerations cannot be used to overcome anticipation. I understand that such secondary considerations include, among other things, commercial success of the patented invention, skepticism of those having ordinary skill in the art at the time of invention, unexpected results of the invention, any long-felt but unsolved need in the art that was satisfied by the alleged invention, the failure of others to make the alleged invention, praise of the alleged invention by those having ordinary skill in the art, and copying of the alleged invention by others in the field. I understand that there must be a nexus, that is, a connection, between any such secondary considerations and the alleged invention. I also understand that contemporaneous and independent invention by others is a secondary consideration tending to show obviousness.

24. I reserve the right to respond to any allegations that may be put forth by Patent Owner in this proceeding that any secondary considerations tend to rebut the obviousness of any claim of the ’635 Patent discussed in this declaration.

D. Claim Dependency

25. I understand that a patent may include two types of claims, independent claims and dependent claims. An independent claim stands alone and includes only the limitations it recites. A dependent claim can depend from an independent claim or another dependent claim. I understand that a dependent claim includes all the limitations that it recites in addition to all of the limitations recited in the claim or claims from which it depends.

E. Priority

26. I have been informed and understand that for a patent’s claims to receive the benefit of priority of an earlier-filed application, every application in the priority chain between that earlier-filed application and the application in question must support every limitation of the claim. This means every parent application must describe every limitation of every claim and that it is not enough for the parent application to simply render obvious the claims of the patent claims in question.

F. Written Description

27. I have been informed and understand that whether an application describes a patent’s claim limitations is known as the “written description

requirement." I have been informed and understand that to satisfy the written description requirement, the patent's specification must describe the claimed invention in sufficient detail that a person of ordinary skill in the art could reasonably conclude that the inventor had possession of the claimed invention at the time of filing. I have been informed and understand that when the above requirement is satisfied, the claims are described as having written-description support.

G. Prior Art Based on Provisional Filing Date

28. I understand a U.S. patent, a U.S. patent application publication, and an international application publication may be afforded a prior art date corresponding to the filing date of a relied upon provisional application only if at least one of the claims in the reference patent, patent application publication, or international application publication (that claim(s) priority to that provisional) and the material relied on from the U.S. patent or U.S. patent application publication, or international application publication are supported by the written description of the provisional application.

H. 35 U.S.C. § 112 ¶6

29. I have been informed and understand that an element in a claim expressed as a means for performing a specified function without the recital of structure, material, or act in support thereof shall be construed to cover the

corresponding structure, material, or acts described in the specification, and equivalents thereof. I have also been informed and understand that such a corresponding structure must be clearly linked or associated to the function recited in the claim by the specification or prosecution history. I was informed and I understand that claim language including "means to" presumptively invokes §112 ¶6.

30. The analysis in this declaration is in accordance with the above-stated legal principles.

IV. MATERIALS CONSIDERED

31. In forming my opinions, in addition to my knowledge and experience, I have considered the materials cited herein and listed in Appendix B.

V. LEVEL OF ORDINARY SKILL IN THE ART

32. It is my understanding that when considering the claims of the '635 Patent and the prior art, I must do so based on the perspective of one of ordinary skill in the art at the relevant effective priority date.

33. As detailed in Section VII.B, (Prosecution History), I understand that the '635 Patent claims priority to a provisional application filed on July 21, 2011. *See* Ex.1001[USP635], Cover. For purposes of my analysis, I have considered the level of ordinary skill in the art as of July 21, 2011. As I further discuss in Section

VII.C, however, the '635 Patent is entitled at most to a priority date of July 20, 2012. I have also considered the level of ordinary skill in the art as of that date, and my opinion is the same as of either date.

34. I understand from Petitioner's counsel that several factors are to be considered in determining who would be a person of ordinary skill in the art. These factors include: (1) the types of problems encountered in the art; (2) the prior art solutions to those problems; (3) the rapidity with which innovations are made; (4) the sophistication of the technology; and (5) the educational level of active workers in the field.

35. Based on these factors as well as my experience and expertise, a person of ordinary skill in the art at all relevant times (hereinafter, a "POSA") would have had at least the equivalent of a Bachelor's degree in mechanical engineering or a related subject or a medical degree with training in neuroscience or a related subject. A POSA also would have a general understanding of brain injury biomechanics and how helmets protect against various brain injuries. A POSA would also have two or more years' experience with design or development of helmets. Less experience working in the field of helmet design or development may be compensated by a higher education level or vice versa.

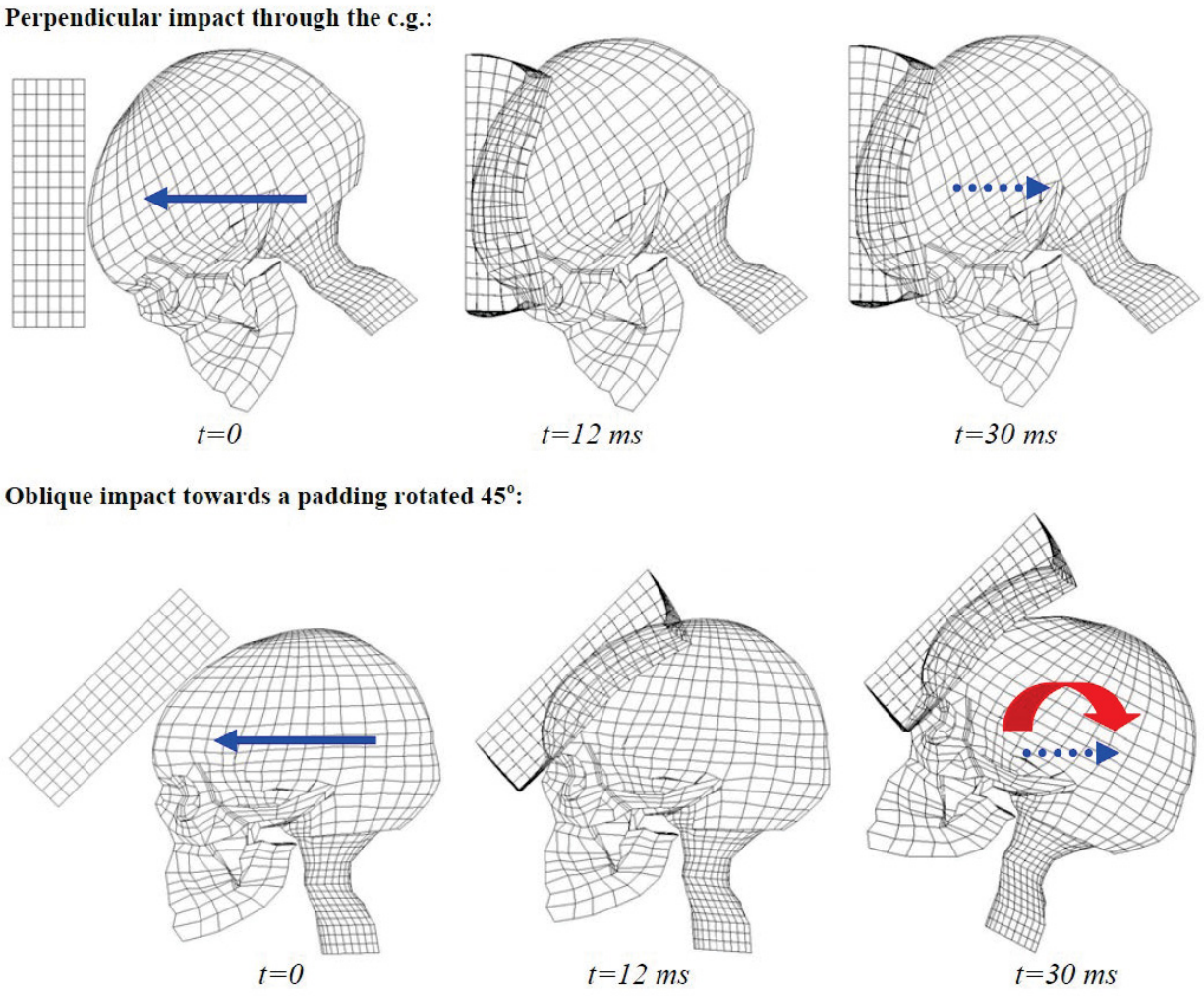
36. Although my qualifications and experience exceeded those of a person of ordinary skill in the art as defined above, my analysis and opinions herein regarding the '635 Patent have been based on the perspective of a person of ordinary skill in the art as of July 21, 2011 or July 20, 2012.

VI. OVERVIEW OF THE TECHNOLOGY

A. Rotational Motion from Impact

37. During a head impact, a person's head and brain are subject to two broad types of impact. Ex.1038[Duma-2005], 4. The first, **linear impact,** also described as direct impact, typically involves a force vector directed toward or near the head's center of gravity. Ex.1026[Kleiven-2007], 4. This force primarily drives translational head motion (acceleration), i.e., causes the brain to move predominantly in a linear direction, e.g., forward-backward, side-to-side, or up-down, eventually followed by a rotation about a pivot point near the neck. *See* Ex.1026[Kleiven-2007], 4. Conversely, **oblique or tangential impact** involves a force vector that is off-center from the head's center of gravity and imparts both linear and rotational acceleration. Ex.1026[Kleiven-2007], 4. The tangential, or angular component of this impact is what causes rotational acceleration, and it leads to a more immediate and pronounced rotational acceleration of the head (often described as a sudden spinning motion) compared to linear impacts. *See*

Ex.1028[Aare-2003], 240-41; *id*., 246 ("A decreased rotational acceleration and a decreased change in rotational velocity causes a decrease in shear strain and shear deformation in brain tissue, which has important implications for the prevention of injuries such as SDH and DAI []."). This force that results in the pronounced rotational acceleration of the head is frequently referred to as "rotational force." *See, e.g.*, Ex.1009[Piper], [0019] ("Protective headgear [] reduces or modulates angular acceleration of the head by reducing or modulating rotational forces acting upon the head."); *see also* Ex.1004[Weber], [0009] (describing reduction of "both rotational and linear forces generated from impacts to the helmets."). These different forces can be visualized with reference to Ex.1026[Kleiven-2007]:



Ex.1026[Kleiven-2007], Fig. 3.

38. Both linear and oblique or tangential impacts are examples of "impact forces," which are forces imparted onto a helmet from any impact. Most collisions involve both types of impacts. Before 2011, the importance of reducing rotational motion of the brain from oblique or tangential impacts was already well understood in the field. "Biomechanically, there is little argument today that it is rotational motion that dominates the nature and extent of brain injury *not* simply linear

translational acceleration." Ex.1025[Newman], 75 (emphasis in original). "[R]otational accelerations have" been found to be correlated with injury "since they result in shear strains inside the brain." Ex.1031[Bosch], 55.

39. The rationale behind the peculiar dangers of rotational acceleration and forces has been understood for years. When the head is impacted, the skull accelerates while the brain lags behind due to its inertia, creating relative motion at the skull-brain interface. Ex.1040[Viano-1989], 407. This relative motion causes strain and pressure within the brain. Although linear acceleration of the skull does cause injuries, they are primarily injuries localized to specific areas, such as contusions and small, focused hematomas. In contrast, rotational acceleration leads to shear strain at the skull-brain interface, which is associated with a range of more diffuse brain injuries such as concussions, more extensive and distributed hematomas (e.g., subdural hematomas), and diffuse axonal injury. *See* Ex.1028[Aare-2003], 240-41; Ex.1039[Ommaya-1985], 250; Ex.1004[Weber], [0005]. In 1985, Ommaya identified six grades of brain injury resulting from rotational acceleration of the head. Ex.1039[Ommaya-1985], 250-51; Ex.1025[Newman], 57-62). Ommaya and Genneralli's "centripetal theory of cerebral concussion and concussive brain injuries" stated that brain injury can be described by a graded set of clinical syndromes whose severity is determined by

mechanically induced strains affecting the brain in a centripetal, or rotational, sequence of disruption. Ex.1039[Ommaya-1985], 250, 267. The effects begin at the surface of the brain and extend inward with increasing levels of rotational acceleration. Ommaya categorized the brain injuries, which escalate in severity from concussion with confusion and amnesia to loss of consciousness to diffuse axonal injury (DAI) of increasing intensity and distribution. DAI is often associated with coma or death.

40. DAI is "one of the most common and important pathologic features of traumatic brain injury (TBI)," and is defined as the tearing of axons in the brain due to "forces such as shear." Ex.1033[Smith-2003], 307. "Shearing"—which can refer to both temporary deforming before returning to original shape (elastic deformation) as well as permanent deformation or tearing due to failure (e.g., ripping or tearing)—results from "shear forces," which arise when adjacent objects or structures experience parallel translational motion in different or opposing directions. In the context of brain injuries, these shear forces develop within brain tissue when the skull rotates around the brain. Specifically, upon a tangential or oblique impact imparting rotational force, the head is primarily accelerated with rotational kinematics, and this rotational acceleration imposes shear forces/shear strains on the

brain tissue due to the inertia-driven delay in brain motion. Ex.1040[Viano-1989], 407.

41. The danger of rotational force from impact was recognized across helmet designers well before 2011. For example, in 2003, Aare et al. described how "[r]otational acceleration of the head is caused mainly by tangential force, which is the most common injury-causing pattern of force in bicycle and motorcycle crashes." Ex.1028[Aare-2003], 240; *id*., 246 ("A decreased rotational acceleration and a decreased change in rotational velocity causes a decrease in shear strain and shear deformation in brain tissue, which has important implications for the prevention of injuries such as SDH and DAI []."). More specifically, rotational motion of the brain from oblique impacts was well-understood as uniquely dangerous compared with linear motion. Ex.1022[Kis-2004], 502 ("rotational acceleration is more damaging than linear").

B. Helmets to Reduce Rotational Motion

42. A helmet functions in multiple ways to mitigate the forces transmitted to the head during an impact. By 2011, a typical helmet contained:

- A hard outer shell, which was typically made from materials such as polycarbonate or fiber reinforced plastic and designed to distribute shock load, prevent penetration, and prevent injury via abrasion;

- At least one softer, foam-based insert next to the harder outer shell, the outermost of which is frequently directly affixed (via glue, tabs, snaps, etc.), to the harder outer shell to absorb direct forces. These next inserts were often made, for example, from expanded polystyrene (EPS) foam or expanded polypropylene (EPP) foam of varying densities depending on specific use cases;
- A soft, flexible foam-based lining conforming to the head, typically made from "low-density, flexible, open-celled, polyurethane or PVC foams" and covered by fabric to interface with the scalp (Ex.1031[Bosch], 2);
- A chin-strap to help maintain helmet positioning and retention.

See, e.g., Ex.1031[Bosch], 2; Ex.1011[Puchalski], 7:19-64, Fig. 1. As one example, below is an exemplary figure of a motorcycle helmet detailing each of the above components:

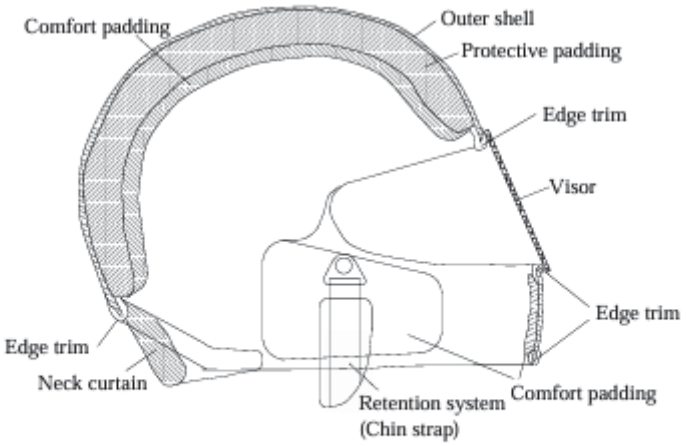


Figure 1.2: Cross section of a full-face motorcycle helmet [UN, 2000].

Ex.1031[Bosch], 2; *see also* Ex.1025[Newman], 21-29. In many helmets, including motorcycle helmets as shown above, the chin-strap typically attaches to the inside of the helmet. The helmet's hard outer shell serves two primary purposes: first, it prevents penetration by ensuring that an impact object does not make direct contact with the head; second, it distributes impact forces over a broader area, thereby reducing localized stress and engaging more of the underlying liner material. Ex.1031[Bosch], 2. Outermost shells are commonly made from rigid polymers such as polycarbonate or ABS, i.e., a stronger material than the inner protective inserts/layers. Ex.1031[Bosch], 2. "The vast majority of [outer] shells, or the first layer of a helmet, are made from polycarbonate—a *robust* material . . . ." Ex.1034[Jans], 1 (emphasis added). EPS, though it is still a solid with reasonable resistance to compression in helmets, has a compressive strength of at least three

orders of magnitude less than that of polycarbonate. For example, two readily accessible industry estimates for EPS and polycarbonate compressive strength give 5-60 psi and 12,000-18,000 psi, respectively. Ex.1036[Intl-Polymer-Solutions]; Ex.1037[Universal-Foam-Products]. EPS is often used in helmets that are designed for single impact events, while EPP is often used for multiple impact event helmets. The mechanical properties of EPS and EPP can be modified to optimize helmet performance. The EPS and EPP material typically used in the deformable inner liner(s)/shells manages impact energy by compressing, crushing, or shearing, thereby increasing the duration over which the force is applied to the head. By extending the time over which the impulse occurs, the peak forces, and therefore the head accelerations, are reduced. Lower head acceleration is generally associated with a reduced risk of head injury, and most current helmet safety standards are based on this principle.

43. Rotational forces act on a helmet in the same way as the brain, causing rotational acceleration and resulting in shear forces/shear strains on the helmet's components. The concept of incorporating features specifically aimed at mitigating rotational head acceleration during impact was well understood before 2011. One common approach involved enabling relative displacement or sliding between helmet components, such as allowing the outer shell to slide relative to the inner

liner. This relative displacement/sliding is and was understood in the field as translation of one layer parallel to another or a surface. *See, e.g.*, Ex.1009[Piper], cl. 1, Fig. 1, [0015], [0017], [0122] (describing "overlapped inner and outer layers attached so as to permit frictional sliding of at least one area of the outer layer over the inner layer" as well as headgear allowing for "sliding of at least one area of the outer layer relative to the inner layer" with "a flowable material intermediate the layers" such as "solid particulates, liquid, gel or gas"). Before 2011, this was achieved in various ways, including through low-friction interfaces, deformable mechanical structures, and/or fluid interfaces. One common technique used in helmet design before 2011 was incorporating components that can deform upon shear forces, either through flexible connection elements or through specialized shell/liner layers and geometrics, producing relative sliding motions. During an oblique or tangential impact imparting rotational force and rotational acceleration, the outer shell may catch or snag on the impact surface, initiating rotation. However, due to partial decoupling between the helmet layers, the outer shell can rotate relative to the inner components that are more rigidly coupled to the head. This relative motion reduces the rotational acceleration transmitted to the head and, thus, shear strain in the brain. Helmets incorporating these features came as early as 2001. These types of helmets have layers that transfer or "transform" energy, such as

impact force or rotational acceleration, into another kind of energy such as potential, kinetic, and to a lesser extent thermal (heat) to reduce force imparted to the brain on impact. For example, Von Holst described an "**outer shell (2)**" and an "**inner (3) shell**" with an intermediate "**sliding layer 4**" for "displacement between" the outer and inner shells:

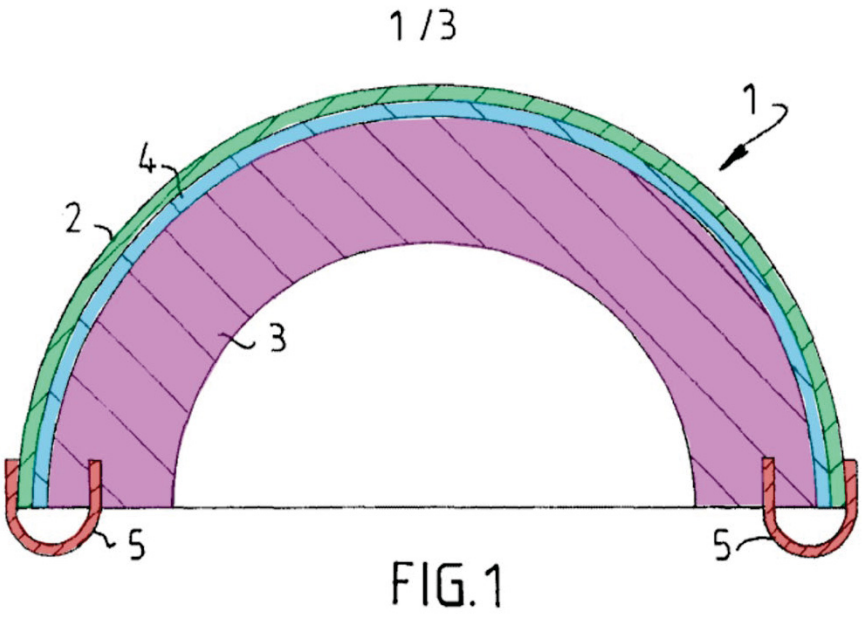


FIG.1

Ex.1005[VonHolst], 4:10-17, Fig. 1.

44. Von Holst explained that this configuration allowing relative sliding reduces "injurious forces" when the outer shell is "displaced relative to the inner shell during simultaneous absorption of rotational energy." *Id.*, 2:34-38; *see also id.*, 8:12-18. This concept of utilizing low friction layers was described in several

additional publications over the years. *See, e.g.*, Ex.1032[Mills-2006], 173-174 ("low friction layers" to reduce "rotational acceleration").

45. Many other examples of helmets with intermediate layers that allow relative movement were known in the prior art. For example, in International Patent Application WO-1996/014768 (Ex.1023, "Phillips"), published May 23, 1996, a helmet is disclosed with an "an intermediate layer" "interposed between [a] hard shell and [an] outer layer, the intermediate layer facilitating relative movement between the shell and outer layer." Ex.1023[Phillips], 4. Further, the intermediate layer of Phillips "may comprise a friction reducing material or lubricant agent which facilitates the movement between the outer layer and [t]he helmet shell." *Id.*

46. Likewise, in U.S. Patent Application 2001/0032351A1 (Ex.1024, "Nakayama"), published October 25, 2001, a helmet is disclosed with a "layer of [an] absorbent elastic body" "provided along the spherical surface" so that the "outer liner and the inner liner can slip relatively easily, so that a degree of freedom in rotational direction becomes large and the rotational component of the shock force can be absorbed more effectively." Ex.1024[Nakayama], [0012]; *id.*, [0010] ("when shock force acts on the helmet . . . rotational acceleration[] . . . is absorbed [effectively].").

47. Additionally, in U.S. Patent Application Publication US2004/0250340 (Ex.1009, "Piper"), published December 16, 2004, "protective headguards" are disclosed that allow sliding between different layers. Ex.1009[Piper], cl. 1, Fig. 1, [0015], [0017], [0122]. Specifically, Piper discloses "protective headguards" such as helmets configured to allow sliding between different layers. Ex.1009[Piper], cl. 1, Fig. 1, [0015], [0017], [0122]. Piper contemplates one embodiment of a headguard "comprising overlapped inner and outer layers attached so as to permit frictional sliding of at least one area of the outer layer over the inner layer" as well as another embodiment of a headguard where the layers are separated by "a flowable material intermediate the layers" such that the "sliding of at least one area of the outer layer relative to the inner layer" is "subject to drag exerted by the flowable material" such as "solid particulates, liquid, gel or gas." Ex.1009[Piper], [0015], [0017], [0122].

48. By 2011, multi-layered helmets with sliding layers were repeatedly described in patents and applications. Ex.1005[VonHolst], 2:34-38, 4:10-17, Fig. 1; Ex.1016[Depreitere], Ex.1010[Ferrara-2006], Ex.1017[Nichols], Ex.1018[Ferrara-2007], Ex.1019[Hawkins], Ex.1009[Piper], Ex.1020[Cripton], Ex.1004[Weber], Ex.1006[Halldin], Ex.1007[Kleiven], Ex.1047[Madey], Ex.1011[Puchalski].

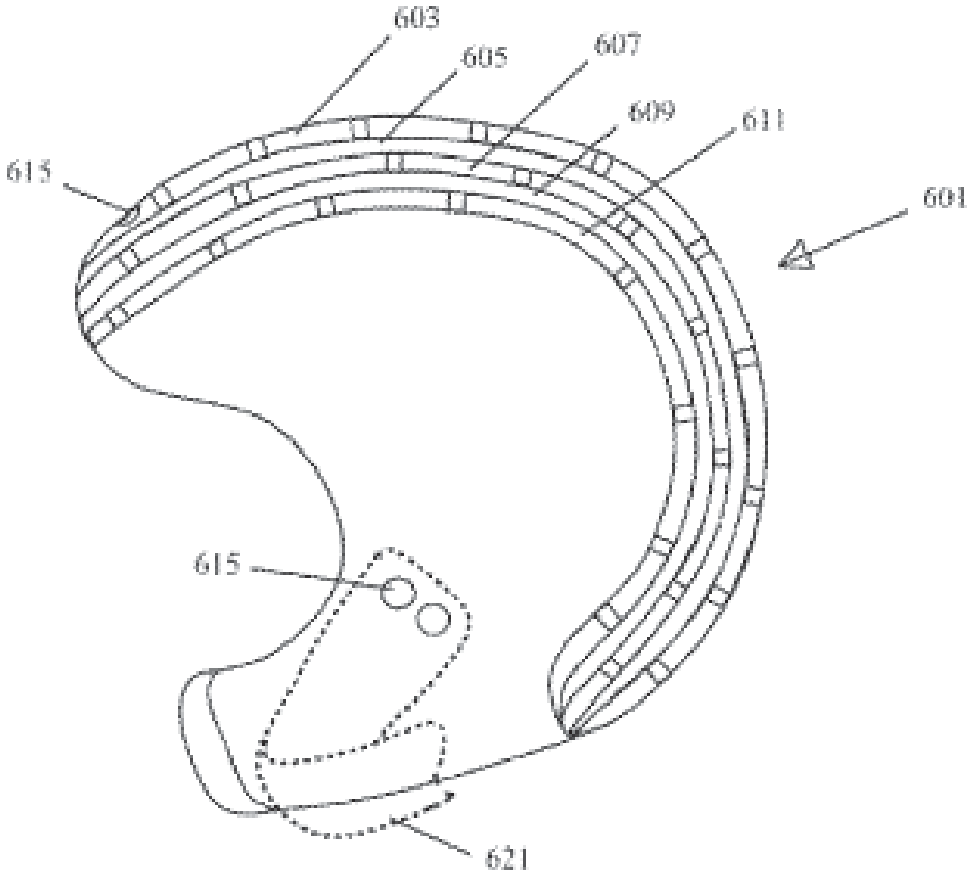
VII. OVERVIEW OF THE '635 PATENT

A. Summary of the '635 Patent

49. The '635 Patent is directed to protective gear designed to reduce damage from impact forces, including rotational forces. Ex.1001[USP635], 2:51-57. Noting the importance of reducing rotational forces on the brain during impact, the patent claims that state-of-the-art helmets of the time "do not sufficiently dampen, transform, dissipate, and/or distribute the rotational, tension, compression, and/or shear forces…." Ex.1001[USP635], 2:64-3:3[1].

50. The '635 Patent purports to overcome such issues with prior art helmets by using helmets with one or more sliding layers to "reduce the movement and/or impact imparted on an outer shell." Ex.1001[USP635], 6:35-38. In Figure 6, the patent depicts a helmet with three layers (603, 607, 611) and "energy and impact transformer" layers (605 and 609):

[1] I understand that the terms "shear mechanism" and "shear layer" are not found anywhere in the specification of the '635 Patent.



Ex.1001 [USP635], 10:3-11, FIG. 6.

The patent's shell layers are "connected" (directly or indirectly) through what the patent refers to as energy and impact transformer layers. Ex.1001[USP635], 10:27-39. These energy and impact transformer layers transfer or "transform" energy, such as impact force or rotational acceleration, into another kind of energy such as potential, kinetic, and heat or rotational energy to reduce force imparted to the brain on impact. *Id.*, 8:65-9:3, 6:10-20, 10:67-11:3.

51. The transformer layer in the ’635 Patent is made using several materials in different combinations. Ex.1001[USP635], 6:29-7:50, 9:29-10:2, 11:3-5. The ’635 Patent discusses layers that slide “relative to” one another, *id.*, 9:5-33, FIG 5 (shell 501 “mov[ing] and/or slid[ing]”[2] relative to middle shell 503), including, for example, an intervening element acting like a lubricant to reduce/remove friction. *Id.*, Abstract, 2:41-47, 6:43-7:4, 7:27-50, 8:57-61 (fluid or gel alone or with mechanical spacers).

52. The ’635 Patent describes other helmet components present in prior art helmets, for example, a lining layer, Ex.1001[USP635], 8:7-10, 10:7-9, and also a chin-strap attached to an inner shell. *Id.*, 10:9-11, 10:23-25.

B. Prosecution History

53. I understand that U.S. Patent Application No. 14/809,142 eventually issued as the ’635 Patent. I also understand that the prosecution in the ’142 application was abbreviated because there was only one office action, in which the Examiner rejected the claims based on double patenting. Ex.1003[Knight-635-FH], 57-62. I understand that after Applicant filed terminal disclaimers in response to the

[2] In my view, the ’635 Patent uses “move relative to” and “slide relative to” synonymously. Ex.1001[USP635], Abstract, 2:37-41, 8:49-56, 9:5-14, 9:15-24.

double patenting rejections, the Examiner allowed the '142 application. Ex.1003[Knight-635-FH], 71, 88-90, 96-100.

54. I also understand that at the same time that Applicant was prosecuting the '142 application ('635 Patent), the Applicant was also prosecuting another U.S. application—No. 13/554,563 (which eventually issued as USPN 10,238,162, Ex.1012)—and that the '563 application claims priority to the same provisional application that the '142 application ('635 Patent) claims priority to. Ex.1013[Knight-162-FH], 48. I also understand that Applicant filed the '563 application on the same day that it filed the application that is the parent application of the '635 Patent (U.S. Application No. 13/554,471, now U.S. Patent No. 8,863,319, Ex.1030[USP319]). The initial '563 application included, for example, the following claims that are similar in whole or in part with the claims of the '635 Patent:

> "1.A helmet, comprising:
>
> an outer shell layer;
>
> a middle shell layer;
>
> an inner shell layer; and
>
> an outer energy and impact transformer layer connecting the outer shell layer to the middle shell layer, wherein the outer energy and impact transformer layer comprises a first plurality of conical structures configured to absorb energy from mechanical forces imparted onto the outer

> shell layer, wherein the outer energy and impact transformer layer allows the outer shell layer to rotate relative to the middle shell layer." Ex.1013[Knight-162-FH], 68.
>
> "12. Protective gear, comprising:
>
> an outer shell layer;
>
> a middle shell layer;
>
> an inner shell layer; and
>
> an inner energy and impact transformer layer connecting the middle shell layer to the inner shell layer, wherein the inner energy and impact transformer layer comprises a second plurality of conical structures configured to absorb energy from mechanical forces imparted onto the middle shell layer, wherein the inner energy and
>
> impact transformer layer allows the middle shell layer to rotate relative to the inner shell layer." Ex.1013[Knight-162-FH], 69.

55. The Examiner rejected the claims on several grounds, including as anticipated by multiple references: U.S. Patent No. 4,213,202, U.S. Patent No. 3,872,511, U.S. Patent Application Publication No. 2007/0190293, and U.S. Patent Application Publication No. US 2006/0059606, each of which the Examiner found taught every limitation of the claims including that "the outer energy and impact transformer layer allows the outer shell layer **to rotate relative to** the middle shell layer." Ex.1013[Knight-162-FH], 118-126 (emphasis added). Following additional rejections, narrower claims were eventually allowed in the '563 application, which

issued at U.S. Patent No. 10,238,162. Ex.1013[Knight-162-FH], 339-348. I understand that none of the references that formed the basis of the anticipation rejection of the substantially similar claims of the ’563 application was disclosed to the Examiner of the ’635 Patent.

C. The ’635 Patent Is Not Entitled to its Earliest Claimed Priority Date

56. I understand that the ’635 Patent claims priority to provisional application No. 61/510,401 filed July 21, 2011 (“Provisional”). Ex.1029[401Prov]. I also understand that in order for Patent Owner to rely on the ’401 Provisional for priority, Patent Owner must show that each application in the chain leading back to the priority application provides written-description support for each claim—that is, that each application must reasonably convey to those skilled in the art that the inventor had possession of the later-claimed subject matter as of the filing date.

57. In my opinion, the Provisional does not provide written description support for the claims of the ’635 Patent. For example, every claim of the ’635 Patent has a “chin-strap” attached to the inner shell layer, “lining layer,” and “shear mechanism.” Ex.1001[USP635], claims 1, 9, 17. However, the Provisional does not describe this. The ’401 Provisional does not describe a chin-strap, nor one that is “attached” to the inner shell or conforming layer as claimed in the ’635 Patent. The ’401 Provisional only refers to such gear designed for a human head in: (1) the

"Description of Related Art" and (2) the description of a "Coconut and Fiber Element" embodiment, which does not refer to sliding. Ex.1029[401Prov], 1-2, 7.

58. The next earliest filed application in the chain (to which the '635 Patent claims priority) that discusses a chin-strap is U.S. Patent Application No. 13/554,471, filed July 20, 2012 (issued as U.S. Pat. No. 8,863,319). Therefore, given the lack of written description support, I understand that July 20, 2012, is the earliest date to which the '635 Patent could claim priority. Ex.1003, 6-11, 72-73

VIII. CLAIM CONSTRUCTION

59. I was informed and I understand that, unless expressly construed, all claim terms are their ordinary and customary meaning, as understood by a person of skill in the art at the time of the invention. I was informed and I understand that the words of the patent's claims and the context in which the term is used in the claims are highly instructive in ascertaining the term's meaning. I further understand that the terms of a claim are to be interpreted in the context of the entire patent, including the patent's claims, its specification, and its figures.

60. I have been further informed and understand that a patent's prosecution history may provide helpful evidence about how the U.S. Patent and Trademark Office and the applicant understood the patent and its claims. Therefore, I have been

instructed that, to the extent relevant, claim terms should also be interpreted in light of the patent's prosecution history.

61. In addition to the claims, the specification, the figures, and the prosecution history, I have been informed and understand that certain "extrinsic evidence," such as scientific or technical references, may also help inform the way in which a person of ordinary skill in the art understands the claim term. I have been informed and understand that extrinsic evidence must always be considered in the context of the intrinsic evidence.

62. For the purposes of this declaration, I will give the claim terms their plain and ordinary meaning, including as understood by a person of ordinary skill in the art in the field at the time of the '635 Patent. For example, the '635 Patent claims contain the following words: "shear mechanism allowing the outer shell layer to slide relative to the inner shell layer [inner conforming layer]." In my opinion, this phrase should receive its plain meaning, which is something that shears and allows the outer protective shell layer to slide relative to the inner protective shell layer. "Shear" or "shearing" can refer to multiple related actions that occur upon taking on a shear load or shear stress that results from shear forces—either temporarily deforming before returning to its original shape (elastic deformation), or permanently deforming or tearing due to failure (*e.g.*, ripping). Either meaning

could be intended depending on the context. From the context of the '635 Patent, which, *e.g.*, describes elastomeric trusses, Ex.1001[USP635], 9:29-31, and the related '909 patent which claims "elastomeric elements" within the shear mechanism in claims 8 and 19, Ex.1050[USP909], cls. 8, 19, I understand "shear" as used in the claims of the '635 Patent to encompass elastic deformation upon taking on a shear load or shear stress. As I noted, shearing results from shear forces which arise when adjacent objects or structures experience parallel translational motion in different or opposing directions. Likewise, it is clear based on claim 2 of the '635 Patent that the shear mechanism recited in this phrase can be a shear layer, which is a layer that shears. Ex.1001[USP635], cl. 2.

63. To the extent an express claim construction is proposed in this proceeding or in another proceeding involving the '635 Patent, I reserve the right to respond to such a construction and/or propose an express construction consistent with the term's plain and ordinary meaning.

IX. PRIOR ART

A. US2012/0198604 ("Weber")

64. I understand that U.S. Application Publication No. US2012/0198604 to Weber et al. ("Weber") was filed on February 8, 2012, and published on August 9, 2012. Ex.1004[Weber], Cover; Ex.1001[USP635], Cover. I understand that Weber

claims priority to U.S. Provisional Application No. 61/462,914 filed February 9, 2011 (Ex.1014[WeberProv]). I have been informed that Weber qualifies as prior art as of its provisional date if the provisional provides written description support as discussed in Section VI above. I have also been informed that the References Cited on the face of the '635 Patent do not include Weber. Ex.1001[USP635], Cover.

65. Weber, consistent with the understandings within the field of helmet design before 2011, states that "rotational acceleration" to a head can lead to "shearing [of] brain tissue." Ex.1004[Weber], [0006]. To protect against such risks, Weber provides multi-layered helmets that "significantly reduce both rotational and linear forces generated from impacts to the helmets…." Ex.1004[Weber], [0009].

66. Weber describes a helmet with an outer liner, intermediate liner, and inner liner, with the inner/intermediate liners and intermediate/outer liners separated by components providing for relative movement between the layers. For example, Weber describes a layer of isolation dampers that allow for "controlled internal omnidirectional relative displacement capability, including relative rotation and translation…." Ex.1004[Weber], [0010], [0042]. Figure 4 describes one of Weber's exemplary helmet containing: 1) **an outer liner** affixed to a hard outer shell, 2) **an intermediate liner**, 3) **an inner liner** affixed to a comfort liner directly contacting a wearer's head, and 4) **isolation dampers** connecting the inner/intermediate and

intermediate/outer liners. These parts of the helmet are shown below with colors corresponding to the colors in the text above.

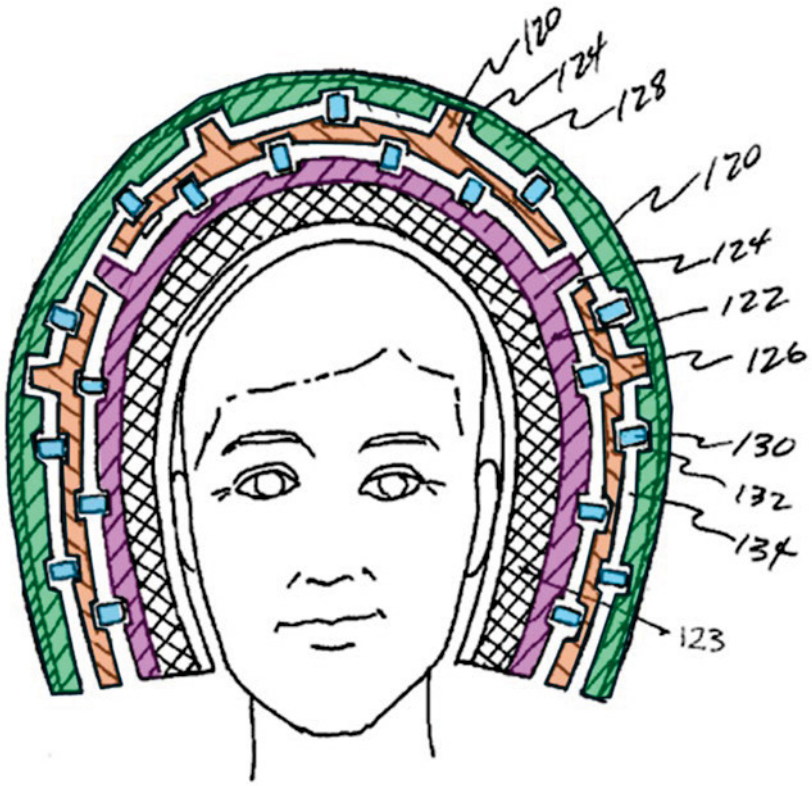


Fig. 4

Ex.1004[Weber], Fig. 4[3], [0045-46].

67. Weber discloses "lugs 120 and corresponding recesses 124 can be configured to allow for a controlled amount of rotational movement between the intermediate liner 126 and the inner and outer liners 122 and 128." Ex.1004[Weber],

[3] All annotations and emphasis have been added unless otherwise stated.

[0045]. Weber explains that "isolation dampers 130" are "disposed between, e.g., the inner and outer liners 122 and 128 and/or the intermediate liner 126 to further dissipate" impact energy, *id.*, *e.g.*, "enabl[ing] the inner and intermediate liners 122 and 126 to move relative to each other and/or the outer liner 128." *Id.*, [0045]-[0046][4].

B. WO01/45526 ("Von Holst")

68. I understand that International Patent Application Publication Number WO01/45526 to Von Holst et al. ("Von Holst") was filed December 21, 1999, and published June 28, 2001, *i.e.*, before the '401 Application was filed on July 21, 2011. Ex.1005[VonHolst], Cover; Ex.1001[USP635], Cover. I have been informed that Von Holst qualifies as prior art. I have also been informed that the References Cited on the face of the '635 Patent identify Von Holst but that it was not cited in an Office Action or substantively discussed by the Examiner during prosecution. Ex.1001[USP635], Cover; Ex.1003[Knight-635-FH], 57-62.

[4] Weber also teaches that "lugs 120 and corresponding recesses 124 can be configured to allow for a controlled amount of rotational movement between the intermediate 126 and the inner and outer liners 122 and 128." Ex.1004[Weber], [0045].

69. Von Holst is directed to helmet designs that allow for sliding movements between layers. For example, it describes in its embodiments, "the outer shell…can be displaced relative to the inner shell during simultaneous absorption of rotational energy…to reduce the injurious forces acting on the wearer…." Ex.1005[VonHolst], 2:34-39.

70. Von Holst Figure 1 depicts a helmet with an **outer shell 2**, an **inner shell 3**, and an **intermediate sliding layer 4** (low-friction layer) allowing displacement between the outer shell and liner. Ex.1005[VonHolst], 4:10-21. A **connecting member 5** further connects outer shell 2, inner shell 3, and intermediate layers, and is "made of, for example, deformable strips of plastic or metal" and "counteract[s] mutual displacement between them by absorbing energy." Ex.1005[VonHolst], 4:38-5:1, 4:10-21. These parts of the helmet are shown below with colors corresponding to the colors in the text above.

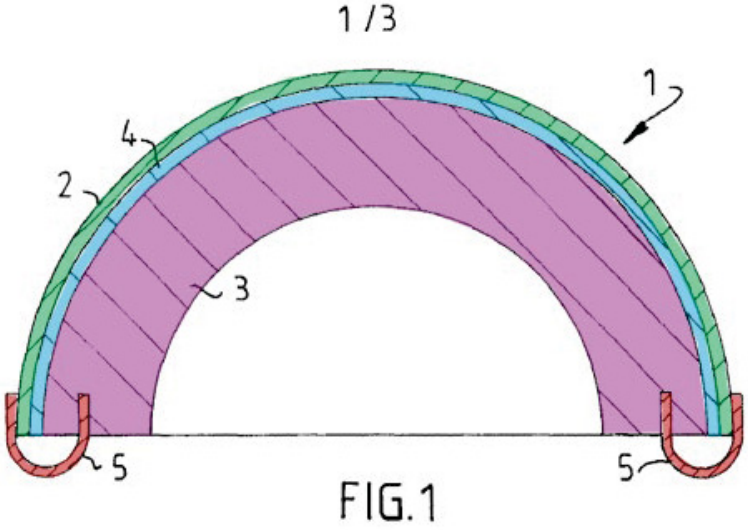


FIG.1

Ex.1005[VonHolst], Fig. 1.

71. Von Holst further depicts variants of the Figure 1 helmet, including a helmet in Figure 3b which includes "**two sliding layers 4**, between which there is an **intermediate shell 6**." Ex.1005[VonHolst], 6:2-6.

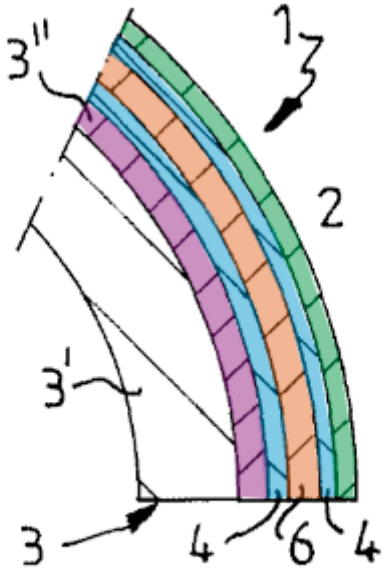


FIG.3b

Ex.1005[VonHolst], Fig. 3b.

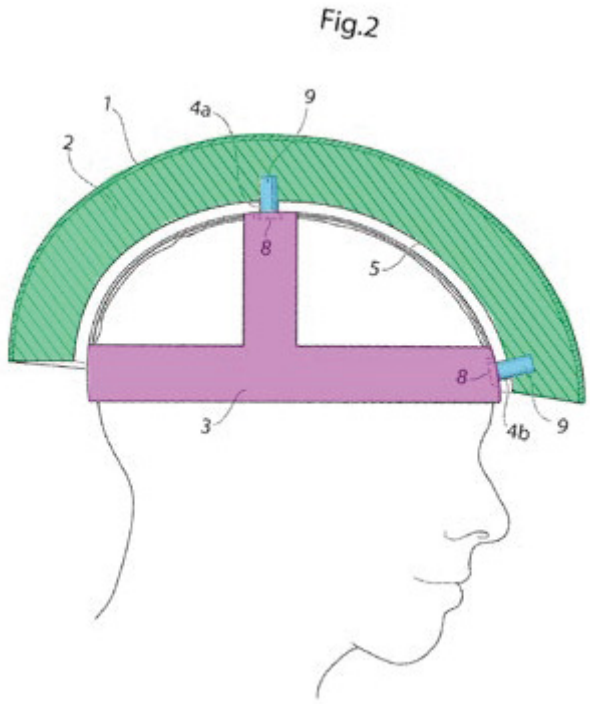
72. Thus, Figure 3b of Von Holst discloses a five-layer helmet with (in addition to connecting member 5) an outer shell connected to an intermediate shell through an outer sliding layer, and the intermediate shell connected to the inner layer/liner through an inner sliding layer.

C. WO2011/139224 ("Halldin")

73. I understand that International Patent Application Publication No. WO2011/139224 to Halldin ("Halldin") was filed on May 3, 2011, and published on November 10, 2011, and claims the benefit of U.S. Provisional Application No. 61/333,817 (filed May 12, 2010) (Ex.1015, "*Halldin Provisional*"), which was filed

before the '401 Application was filed on July 21, 2011. Ex.1006[Halldin], Cover; Ex.1001[-[USP635], Cover. I have been informed that Halldin qualifies as prior art as of its provisional date if the provisional provides written description support as discussed in Section VI above. I have also been informed that the References Cited on the face of the '635 Patent do not identify Haldin. Ex.1001[USP635], Cover.

74. Halldin is directed to the problem of "reduc[ing] the amount of rotational acceleration affecting the brain." Ex.1006[Halldin], [0013]. Halldin discloses a helmet with an **outer shell 1, energy absorbing layer 2**, and **inner attachment device 3.** Ex.1006[Halldin], [0046], [0047]. The attachment device is fixated to the energy absorbing layer by **fixation members 4a and 4b**, which upon impact allow "the energy absorbing layer 2 to slide in relation to the attachment device 3." Ex.1006[Halldin], [0046], [0047]. These parts of the helmet are shown below with colors corresponding to the colors in the text above.



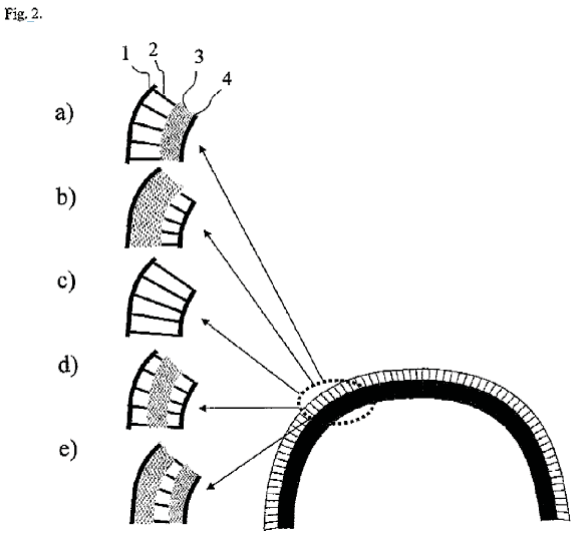
Ex.1006[Halldin], Fig. 2.

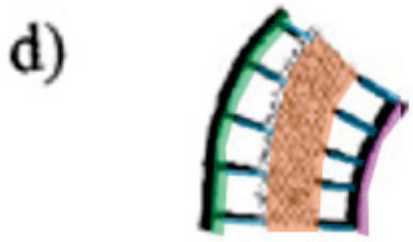
D. US2013/122256 ("Kleiven")

75. I understand that U.S. Application Publication No. US2013/0122256 to Kleiven et al. ("Kleiven") was filed on May 12, 2011, and published on May 16, 2013, and claims the benefit of U.S. Provisional Application Nos. 61/395,344 (filed May 12, 2010) and 61/395,386 (filed May 12, 2010), both filed before the '401 Application was filed on July 21, 2011. Ex.1007[Kleiven], Cover; Ex.1001[USP635], Cover. I have been informed that Kleiven qualifies as prior art. I have also been informed that the References Cited on the face of the '635 Patent do not include Kleiven. Ex.1001[USP635], Cover.

76. Kleiven recognizes that "[a]ngular or rotational motion is induced by an oblique impact and is considered to cause a relatively greater damage to the brain than linear acceleration." Ex.1007[Kleiven], [0004]. To "reduce[] angular/rotational motion," Kleiven discloses a helmet having two or more "layers" separated by flexible "spikes or beams" that permit displacement of the surrounding layers. Ex.1007[Kleiven], Abstract, [0002], [0020], [0048], [0049], [0062].

77. Figures 1 and 2 disclose helmets with an **outer shell 1**, **inner shell 4**, **spike layer 2**, and **energy absorbing foam layer 3**. Ex.1007[Kleiven], [0031], Fig. 2. Figure 2(d) shows a five-layer embodiment: **inner** and **outer** shell layers, **intermediate layer of energy absorbing foam**, and two **spike/beam layers** separating the **foam layer** and permitting relative movement between the **inner** and **outer** shell layers. Ex.1007[Kleiven], [0031], Fig. 2; *id.*, [0020], [0048] (invention can have "[o]ne or several intermediate layers that move relative to each other or to the inner or outer layer"). These parts of the helmet are shown below with colors corresponding to the colors in the text above, specifically for the Figure 2(d) embodiment.





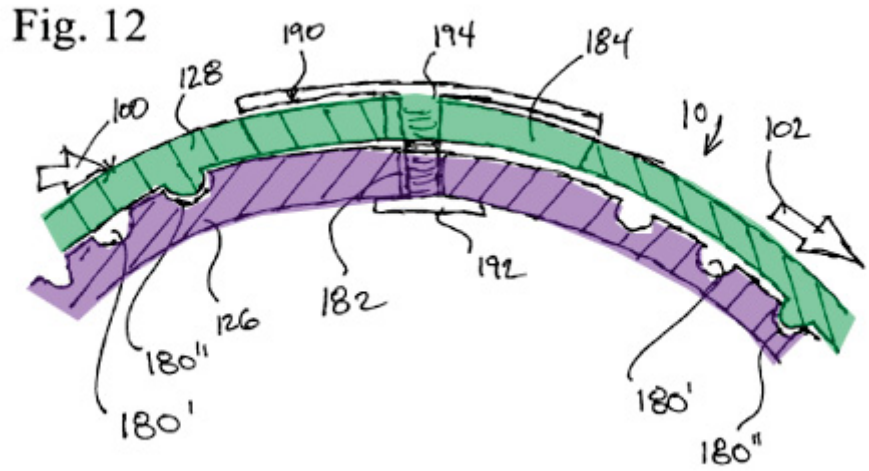
Ex.1007[Kleiven], Fig. 2, 2(d).

78. In addition to the relative sliding of the outer/middle and middle/inner layers, Kleiven's spikes/beams are "flexible, plasticizing, yielding or frangible," Ex.1007[Kleiven], [0048], allowing them to yield upon a force to the outer layer, and thus allowing the outer layer to contact and slide relative to the middle layer, or middle layer relative to the inner layer. *See* Ex.1007[Kleiven], Fig. 12.

E. US6,996,856 ("Puchalski")

79. I understand that U.S. Patent No. 6,996,856 was filed as U.S. Application No. 11/103,533 on April 12, 2005, claims priority to U.S. Patent Application No. 10/372,938 filed February 26, 2003, and that Puchalski issued on February 14, 2006. I have been informed that Puchalski qualifies as prior art.

80. Puchalski teaches a helmet "including a generally two-part dome shaped shell 14 which includes a **separate and distinct inner dome-shaped panel 126** and an **outer dome-shaped panel 128**." Ex.1011[Puchalski], 11:36-39. Upon application of "impact force", the outer panel on Puchalski's helmet will slide relative to its inner panel: "upon the application of a predetermined minimum impact force (Arrow 100) on the outer panel 128, the impact force results in the sliding movement of the outer panel 128 relative to the inner panel 126":



Ex.1011[Puchalski], 12:55-58, Fig. 12.

81. Puchalski's helmet can also include chin-straps attached to the inner panel: "[a]lthough not essential, most preferably, the **helmet chin straps 16** are secured to the peripheral edge of the **inner panel 126**, along each of its sides." Ex.1011[Puchalski], 12:1-3. I reproduce below Figs. 9-10 of Puchalski which show these features and their relative positions in the helmet:

Fig. 9

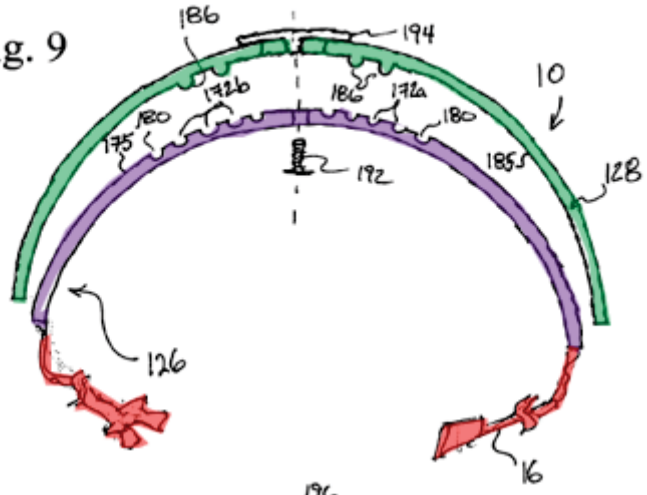
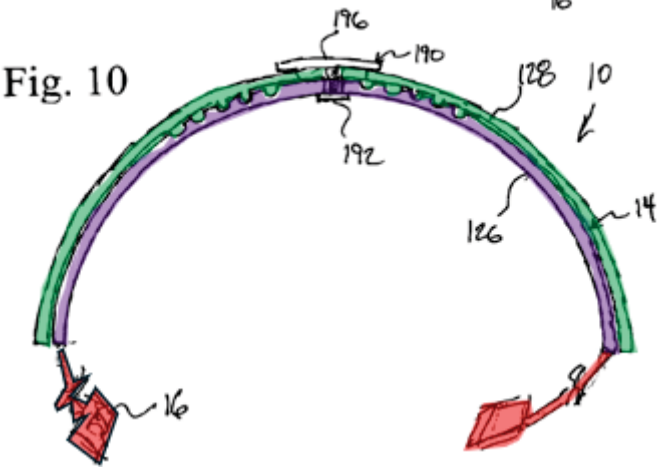


Fig. 10

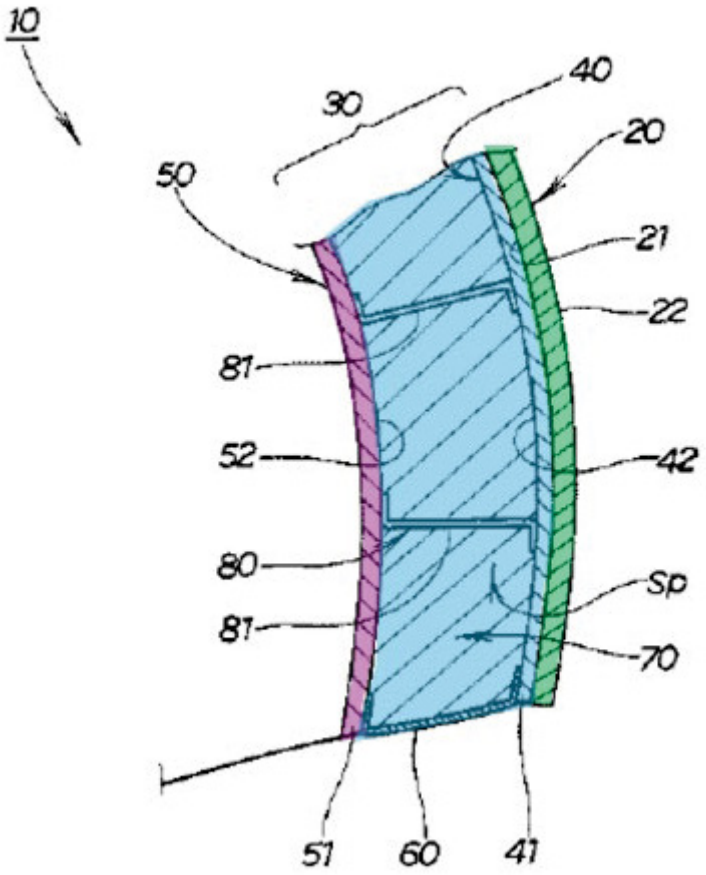


Ex.1011[Puchalski], Figs. 9-10.

F. JP2006/016740 ("Dotsuko")

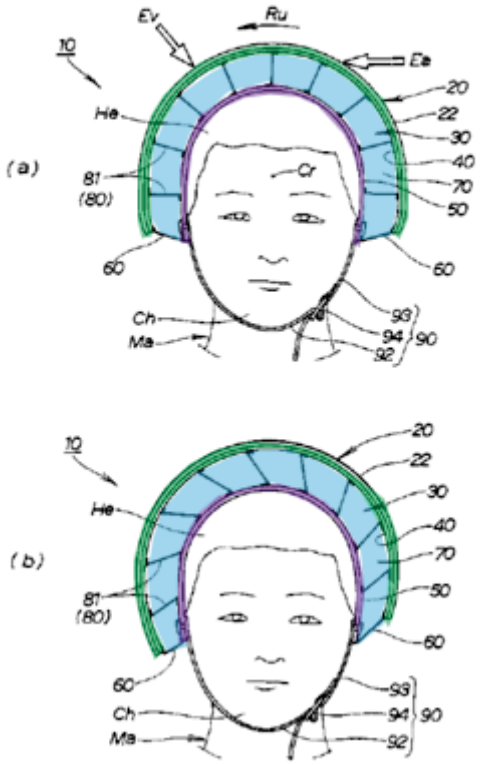
82. I understand that JP2006/016740 is a Japanese patent application publication that was filed on July 5, 2004, and published on January 19, 2006. I have been informed that Dotsuko qualifies as prior art. Ex. 1041[Dotsuko], (English translation of Ex.1042[Dotsuko-Original-Japanese]).

83. Dotsuko describes a helmet with **inner liner 50** (inner shell layer) connected to **outer liner 40 and outer shell 20** (outer shell layer) with a **layer of space Sp** comprising a plurality of elastic straps and an elastic body disposed between the inner and outer layers. Ex.1041[Dotsuko], [0013], [0017].



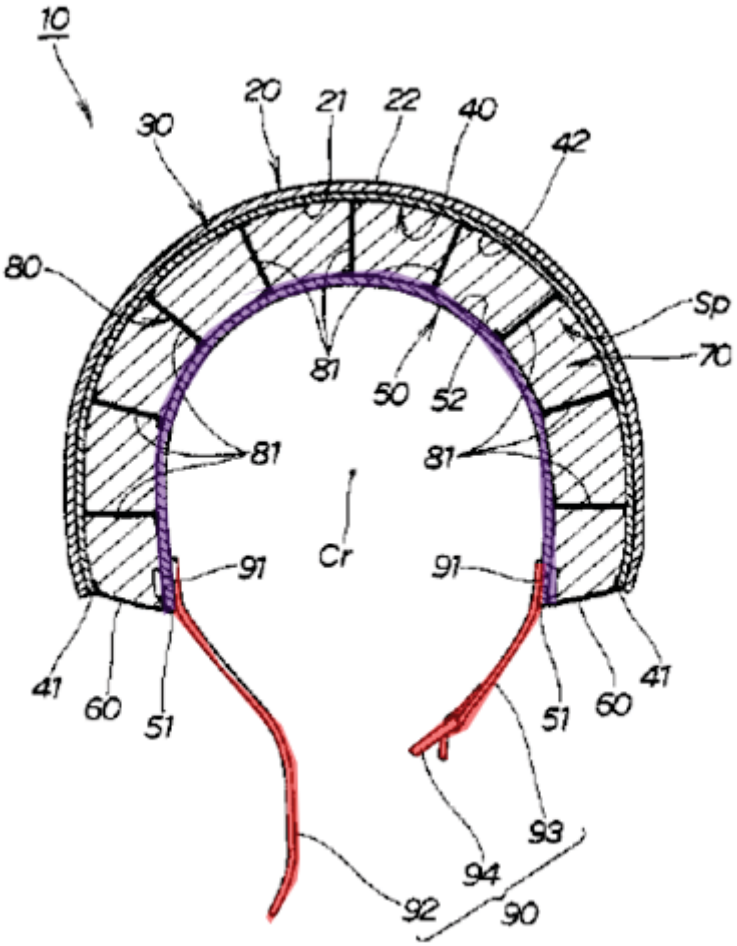
Ex.1041[Dotsuko], Fig. 2. Dotsuko teaches that its outermost shell 20 is "made of a resin molded product such as FRP (fiber-reinforce plastic)," and "[t]he outer liner 40 and the inner liner 50 are resin products made of, for example, a hard resin or a soft resin." Ex.1041[Dotsuko], [0012], [0014]. Dotsuko's elastic body can "deform" and the straps "allow a certain degree of relative rotation of the shell 20 and the outer liner 40 with respect to the inner liner 50…." Ex.1041[Dotsuko], [0016], [0017].

[Fig. 4]



Ex.1041[Dotsuko], Fig. 4.

84. As can be seen in Figure 3 below, Dotusko also discloses a **chin-strap 90** "attached to the lower portions on the left and right sides of the **inner liner 50**…." Ex.1041[Dotsuko], [0018].



Ex.1041[Dotsuko], Fig. 3. The chin-strap helps the liner to be "fixed to the head." As such, upon impact, "the inner liner 50[] remains in place while the shell 20 alone relatively rotates in the direction of the force, thereby absorbing the impact energy Ea." Ex.1041[Dotsuko], [0022].

G. US2004/0117896 ("Madey")

85. I understand that U.S. Application Publication No. US2004/0117896 to Madey et al. ("Madey") was filed on July 10, 2003, and published on June 24, 2004, which claims the benefit of U.S. Provisional Application No. 61/416,312 (filed October 4, 2002), *i.e.*, before the '401 Application was filed on July 21, 2011. Ex.1047[Madey], Cover. I have been informed that Madey qualifies as prior art.

86. Figure 4A discloses helmet with **outer helmet layer 43/44**, **inner helmet layer 41**, and **interface layer 45**, which "allows the outer helmet layer to displace with respect to the inner helmet layer, thereby absorbing and/or diverting forces…." Ex.1047[Madey], Abstract, [0025], Fig. 4. Figure 9B describes an embodiment where "**interface layer 94** disposed between [outer and inner] layers 90 and 92…comprises a lamellar structure of **hyper-elastic columns 96**," that buckle under an impact force to absorb impact energy. Ex.1047[Madey], [0037]. These parts of the helmet are shown below with colors corresponding to the colors in the text above.

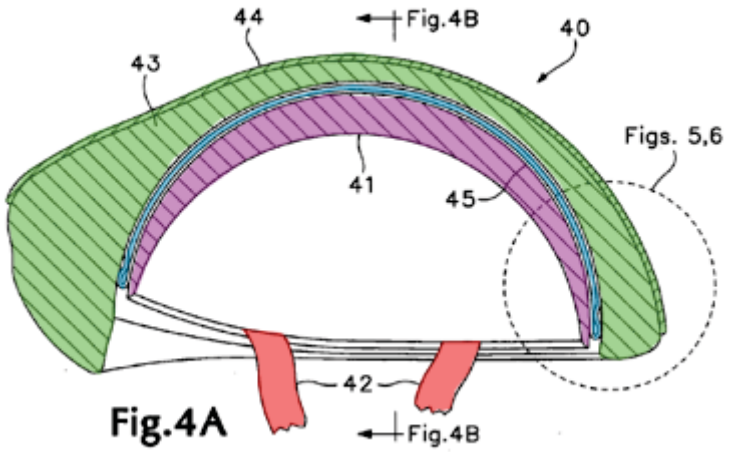


Fig.4A

Ex.1047[Madey], Fig. 4A.

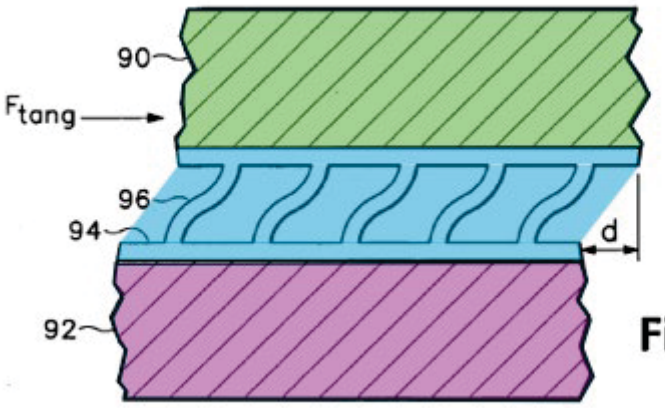


Fig.9B

Ex.1047[Madey], Fig. 9B. Madey's helmet can also include chin-straps attached to the inner panel: "a helmet retention system (e.g., **straps 42** and foam padding inserts, not shown) to affix inner helmet layer 41 to a wearer's head…." Ex.1047[Madey], [0025], [0005] ("A helmet retention system (e.g., straps 26) allows the user to attach the helmet securely to the head, usually with a chinstrap and increasingly with a

suspended rear strap or member that aligns the helmet properly on the wearer's head."), Fig. 4A.

X. GROUNDS FOR FINDING THE CHALLENGED CLAIMS INVALID

87. It is my opinion that the Challenged Claims are unpatentable on the following grounds.

- **Ground 1:** Claims 1-4, 6, 8-12, 14, and 16-20 are Obvious over Weber Combined with Puchalski
- **Ground 2:** Claims 1-4, 6, 8-12, 14, and 16-20 are Obvious over Von Holst Combined with Halldin and Puchalski
- **Ground 3:** Claims 1-4, 6, 8-12, 14, and 16-20 are Obvious over Kleiven Combined with Puchalski
- **Ground 4:** Dotsuko Anticipates Claims 1-3, 9-11, and 17-19
- **Ground 5:** Claims 8 and 16 are Obvious over Dotsuko Combined With Puchalski
- **Ground 6:** Madey Anticipates Claims 1-3, 8-11, and 16-19

88. The below discussion demonstrates in detail that claims 1-4, 6, 8-12, 14 and 16-20 of the '635 Patent are unpatentable as obvious. A copy of the Challenged Claims is attached as Appendix C.

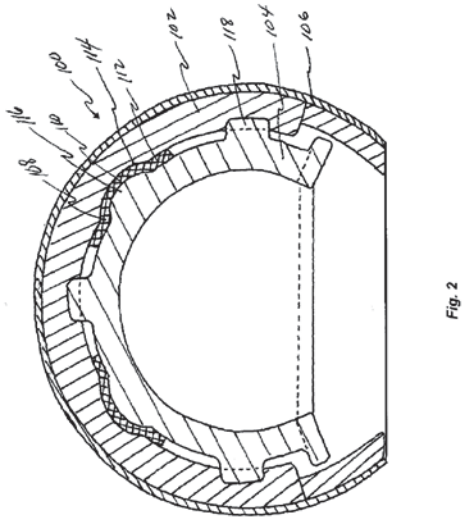
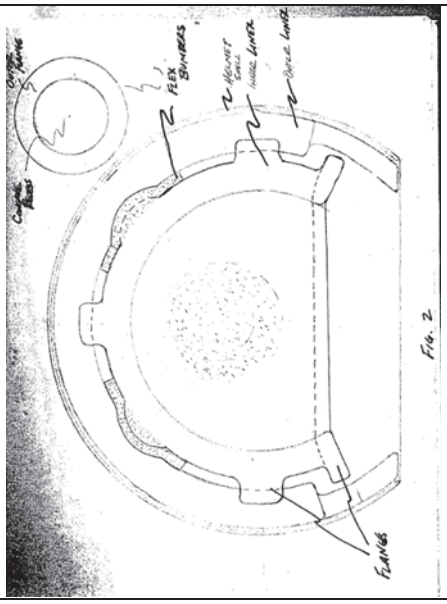
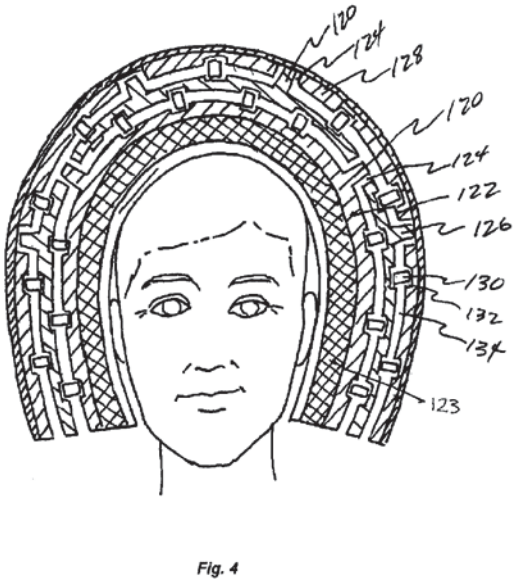
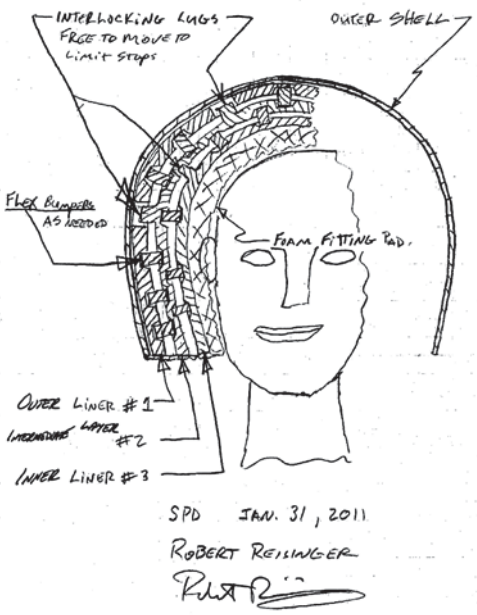
A. Ground 1: Claims 1-4, 6, 8-12, 14, and 16-20 are Obvious over Weber in view of Puchalski

1. Support for Weber in its Provisional Application

89. I have been informed and understand that a published patent application is entitled to use the filing date of a beneficially claimed provisional application as an effective prior art date, so long as the subject matter relied on in the application is described in the provisional application and at least one of the claims in the application is supported by the written description of the provisional application.

90. It is my view that the subject matter relied on in Weber is described in the Weber Provisional application. In the below chart, I have summarized where each part of Weber's disclosure that I rely upon in my analysis finds written description support in the Weber Provisional. In short, based on my review of the Weber Provisional, it conveys to a person of ordinary skill in the art that the applicants of Weber had provided written description in that Weber Provisional of each disclosure I rely upon from Weber.

Weber (Ex.1004)	Weber Provisional (Ex.1014)
FIG. 2	FIG. 2

 Fig. 2	 Fig. 2
FIG. 4	FIG. 3
 Fig. 4	 FIG. 3
[0002] "One or more embodiments of the present invention generally relate to safety equipment, and more particularly, to protective helmets that protect the human head against repetitive impacts, moderate impacts	p. 3 "The present invention relates to protection of the human head in the event of an accident where an individual is wearing a safety helmet. In particular, the present invention will reduce the likelihood of rotational brain

and severe impacts so as to significantly reduce the likelihood of both translational and rotational brain injury and concussions."	injury, shearing of brain matter, linear compression, and / or concussion in accident situations."
[0006] "[G]iven the distribution of brain matter, even direct linear or translational impacts can generate shear forces within the brain sufficient to cause rotational brain injuries."	p. 3 "[T]he present invention will reduce the likelihood of rotational brain injury, shearing of brain matter, linear compression…." "When force applied to the helmet exceeds the capability of the combined resources of the helmet, including the interior padding, to manage the force, energy that is not absorbed by the helmet is transferred to the head and brain of the user. This may result in moderate concussion or severe brain injury, including a rotational brain injury depending on the type of impact energy, and the severity of the impact energy."
[0008] "Safety helmets are designed to absorb and dissipate as much energy as possible over the greatest amount of time possible. Whether the impact causes direct linear or translational acceleration/deceleration forces or angular acceleration/deceleration forces, the helmet should eliminate or substantially reduce the amount of energy transmitted to the user's head and brain."	p. 4 "The desired function of helmets is to absorb and dissipate as much energy as possible, in the shortest amount of time possible, be it direct linear translational energy, or angular acceleration or deceleration energy in the event of any given accident situation, without transmitting that energy to the wearer's head form and brain. The goal of these helmets is to reduce or significantly diminish the risk of head and brain injury resulting from these various situations."
[0009] "[O]mnidirectional impact energy management systems are provided for	p. 4 "The present invention is an omni-directional impact energy management

protective helmets that can significantly reduce both rotational and linear forces generated from impacts to the helmets over a broad spectrum of energy levels."	system for a helmet. The present invention seeks to significantly reduce the rotational and linear forces on the brain that are generated from impacts to a helmet."
[0034] "In accordance with one or more embodiments of this disclosure, omnidirectional impact energy management systems for helmets are provided that can significantly reduce both rotational and linear forces generated from impacts imparted to the helmets. The systems enable a controlled internal omnidirectional relative displacement capability, including relative rotational and translational movement, between the internal components of a hard shelled safety helmet."	p. 4: "The present invention is an omni-directional impact energy management system for a helmet. The present invention seeks to significantly reduce the rotational and linear forces on the brain that are generated from impacts to a helmet."; "The present invention allows a controlled internal omni-directional displacement capability, including rotation, among interior components of a hard shelled safety helmet."
[0036] "In accordance with one or more example embodiments hereof, safety helmets can comprise at least two layers. One of these layers, an inner liner, is disposed in contact with the wearer's head, either directly or via a fitment or so-called 'comfort liner.'"	p. 4, 5, 6, "The present invention allows a controlled internal omni-directional displacement capability, including rotation, among the interior components of a hard shelled safety helmet. Generally, the present invention relates to a safety helmet comprising at least two layers housed within the hard exterior shell of the helmet. One of these layers, the inner liner, is in contact with the wearer's head. Another layer, the outer liner, is affixed to the hard outer shell of the helmet. One or more intermediate layers may be disposed between the inner and outer layers."

	"The liners may be multi or single-density EPS liners or may be comprised of any other suitable materials. The inner liner may be static and engaged directly by the individual's head through the use of a comfort liner and or fit pads common in all sporting helmets." "An engineered limit (or stop) may.be designed into and between the interior liners to prevent over-rotation or displacement between the interior liners due to the displacement of the exterior helmet shell assembly during an accident. In one exemplary embodiment the inner liner is provided with multiple flanges extending outward from the inner liner to act as rotational 'stops' by impacting with the edge of the outer liner. In other exemplary embodiments, an additional layer is inserted between the inner liner and outer liner. This layer, like the inner and outer liners, may be formed of EPS or any other suitable materials."
[0037]	p. 4, 5 "In an exemplary embodiment of the invention, the outer surface of the inner liner is connected to the inner surface of the outer liner with components that will allow for controlled omnidirectional relative displacement between the liners. Thus the two liners are engaged with each other such that they can displace relative to each other in response to angular forces from a

"In an example embodiment, an outer surface of an inner liner is coupled to[5] an inner surface of an outer liner, which can have an outer surface affixed to an inner surface of the hard outer shell of the helmet, with shock absorbing and dampening components that enable controlled, omnidirectional relative rotational and translational displacements to take place between the inner and outer liners. Thus, the two liners are coupled with each other	glancing indirect or direct below to the hard outer shell of the helmet. The engagement between the inner and outer liners allows for limited, controlled, omni-directional movement to reduce the transfer of forces and resulting acceleration originating from the hard outer shell of the helmet."

[5] Weber uses the term "coupled" in certain instances here and elsewhere in places where Weber Provisional uses the term "connect" or engage." I have reviewed these disclosures, and Weber's language corresponds to how the Weber Provisional describes and depicts connection and engagement in its specification and Figures. Weber also uses these terms interchangeably: "Thus, **the two liners are coupled with each other** in such a way that they can displace relative to each other omnidirectionally in response to both angular and translational forces from a glancing or direct blow to the hard outer shell of the helmet. **The engagement between the inner and outer liners** enables a controlled, omnidirectional relative movement between the two liners to reduce the transfer of forces and resulting accelerations originating from the hard outer shell of the helmet to the head and brain of a wearer." Ex.1004[Weber], [0037].

in such a way that they can displace relative to each other omnidirectionally in response to both angular and translational forces from a glancing or direct below to the hard outer shell of the helmet. The engagement between the inner and outer liners enables a controlled, omnidirectional relative movement between the two liners to reduce the transfer of forces and resulting accelerations originating from the hard outer shell of the helmet to the head and brain of a wearer."	
[0038] "The relative movement of the inner and outer layers or liners can be controlled via various suspension, dampening, and motion controlling components that are disposed between the liners and couple them together for relative movement. In some embodiments, additional liners or partial liners can be inserted between the inner and outer liners. Thus, the energy absorbing structure can comprise various liner components, with or without air gaps between them, that enable such controlled omnidirectional relative displacement between one or more of the liners. The liners and other layers can comprise multi- or single-density EPS… ."	p. 5 "The relative movement of the inner and outer layers is controlled via various means of suspension, dampening, and motion controlling components that engage the liners. Additional layers or partial layers may be inserted between the inner liner and the outer liner in such a way that would comprise various layers of components, with or without air gaps between them, that would allow for such controlled omni-directional relative displacement between one or more of the layers. In an exemplary embodiment, two energy-absorbing liners are engaged within one another forming an assembly with complete omni-directional orbital capability established within specific definite range of movement margins. The liners may be multi or single-density EPS liners or may be comprised of any other suitable materials."

[0039] "[T]he outer liner 102 is attached directly to the inside surface of the helmet shell 106, as is typical in conventional helmet design. The relatively hard outer shell 106 can be manufactured from conventional materials, such as fiber-resin lay-up type materials, polycarbonate plastics, polyurethane, or any other appropriate materials…."	p. 5 "The outer liner is affixed directly to the inside surface of the helmet shell as is commonplace in traditional helmet design. The traditional helmet shell may be manufactured from common materials such as fiber lay-up resin type materials, polycarbonate plastics, or other appropriate materials."
[0040] "The inner and outer liners **104** and **102** are coupled to each other so as to form an internal Subassembly by the use of a plurality of resilient, e.g., elastomeric, structures referred to herein as 'isolation dampers.' As illustrated in FIG. 2, the isolation dampers **108** can comprise a generally circular disk having a concave, e.g., generally spherical, recess 110 disposed in a lower Surface thereof, a correspondingly shaped convex protrusion extending from an upper Surface thereof, and a flange **112** extending around the circumfery thereof. The inner liner 104 can include a plurality of convex, e.g., generally spherical, protrusions **116**, each disposed in spaced opposition to a corresponding one of a plurality of correspondingly shaped concave recesses **114** disposed in the outer liner **102**."	p. 5 "The inner and outer liners engage each other to form an internal sub-assembly by the use of a plurality of flexible or elastomeric structures referred to herein as flex bumpers or isolation dampers. In one exemplary embodiment shown in Fig. 2, the flex bumpers are generally circular with a circular concave recess and an outer flange. The flex bumpers fit between the inner liner and the outer liner such that the concave recess nests within a recess in the outer liner. A corresponding raised section of the inner liner nests within the concave recess. In another design embodiment the flex bumpers could connect to the inside surface of the outer hard shell directly."
[0041] "In an embodiment, one or both of the concave and convex features of the isolation dampers 108 can be	p. 5 "The inner and outer liners engage each other to form an internal sub-assembly by the use of a plurality of

complementary in shape to one or both of those of the concave and convex features of the inner and outer liners 104 and 102, respectively. The isolation dampers 108 are disposed between the inner and outer liners 104 and 102 such that their concave recesses 110 are respectively disposed over a corresponding one of the convex protrusions 116 on the inner liner 104, and the convex protrusions on the isolation dampers 108 are respectively disposed within corresponding ones of the concave recesses 114 in the outer liner 102."	flexible or elastomeric structures referred to herein as flex bumpers or isolation dampers. In one exemplary embodiment shown in Fig. 2, the flex bumpers are generally circular with a circular concave recess and an outer flange. The flex bumpers fit between the inner liner and the outer liner such that the concave recess nests within a recess in the outer liner. A corresponding raised section of the inner liner nests within the concave recess. In another design embodiment the flex bumpers could connect to the inside surface of the outer hard shell directly."
[0041] "In an embodiment, one or both of the concave and convex features of the isolation dampers 108 can be complementary in shape to one or both of those of the concave and convex features of the inner and outer liners 104 and 102, respectively. The isolation dampers 108 are disposed between the inner and outer liners 104 and 102 such that their concave recesses 110 are respectively disposed over a corresponding one of the convex protrusions 116 on the inner liner 104, and the convex protrusions on the isolation dampers 108 are respectively disposed within corresponding ones of the concave recesses 114 in the outer liner 102."	p. 5 "The inner and outer liners engage each other to form an internal sub-assembly by the use of a plurality of flexible or elastomeric structures referred to herein as flex bumpers or isolation dampers. In one exemplary embodiment shown in Fig. 2, the flex bumpers are generally circular with a circular concave recess and an outer flange. The flex bumpers fit between the inner liner and the outer liner such that the concave recess nests within a recess in the outer liner. A corresponding raised section of the inner liner nests within the concave recess. In another design embodiment the flex bumpers could connect to the inside surface of the outer hard shell directly."
[0042]	pp. 4, 5

"[T]he the outer liner 102 is affixed directly to the inside surface of the outer shell 106…."	"Another layer, the outer liner, is affixed to the hard outer shell of the helmet." "The outer liner is affixed directly to the inside surface of the helmet shell as is commonplace in traditional helmet design."
[0043] "As illustrated in FIGS. **2** and **3**, plurality of the isolation dampers **108** can be provided at selected points around the circumfery of the helmets **100** or **150**. Different isolation dampers 108 can be designed for specific applications and effectively 'tuned' to manage the anticipated rotational and translational forces applied thereto. The isolation dampers 108 can be variously configured to control the amount of rotational force that will cause displacement of the various liners of the helmet **100** and, as discussed in more detail below, can be configured such that they will tend to cause the inner liner **104** to return to its original position relative to the outer liner **102** after the force of an impact is removed from the helmet **100** or **150**. It will be readily apparent to those skilled in the art that isolation dampers **108** can be configured in a wide range of configurations and materials varying from those shown and described in the example embodiments, and the general principles described herein can be applied without departing from the spirit and scope of the invention."	p. 5, 6 "The inner and outer liners engage each other to form an internal sub-assembly by the use of a plurality of flexible or elastomeric structures referred to herein as flex bumpers or isolation dampers. In one exemplary embodiment shown in Fig. 2, the flex bumpers are generally circular with a circular concave recess and an outer flange. The flex bumpers fit between the inner liner and the outer liner such that the concave recess nests within a recess in the outer liner. A corresponding raised section of the inner liner nests within the concave recess. In another design embodiment the flex bumpers could connect to the inside surface of the outer hard shell directly. A plurality of such flex bumpers may be provided at various points around the helmet. These flex bumpers provide the ability to control and tune the amount of rotational force that will cause displacement of the outer liner relative to the inner liner, and can be configured such that they will tend to cause the inner liner to return to its original position in reference to the outer liner after the

	force is removed, functioning in a fashion similar to a ball and socket detent. The flex bumpers can be arranged in various modifications to the embodiments as will be readily apparent to those skilled in the art, and general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the invention."
[0045] "Such 'intermediate' liners can be formed of, for example, EPS…, or any other suitable materials." "[I]solation dampers 130 of various configurations can also be disposed between, e.g., the inner and outer liners 122 and 128 and/or the intermediate liner 126 to further dissipate the energy of impacts." "[A] 'comfort' liner 123 configured to closely surround the head of the wearer can be attached or otherwise coupled to an inner surface of the inner liner 122."	pp. 4, 5, 6 "One or more intermediate layers may be disposed between the inner and outer layers. These layers may be formed of any suitable material, including without limitation such materials commonly used in the industry such as expanded polystyrene (EPS)." "The liners may be multi or single-density EPS liners or may be comprised of any other suitable materials." "In other exemplary embodiments, an additional layer is inserted between the inner liner and outer liner. This layer, like the inner and outer liners, may be formed of EPS or any other suitable materials."

	"Flex bumpers[6] of various configurations can be placed between the liners and/or the middle layer to further dissipate energy." "The liners may be multi or single-density EPS liners or may be comprised of any other suitable materials. The inner liner may be static and engaged directly by the individual's head through the use of a comfort liner and or fit pads common in all sporting helmets."
[0046] "[T]he isolation dampers 130 can be cylindrical in shape, and configured such that they engage within corresponding recesses 132 in the adjacent surfaces of the inner, intermediate and outer liners 122, 126 and 128 so as to create a space or air gap 134 between the respective opposing surfaces thereof. The isolation dampers 130 can be configured to flex, bend, and/or compress to absorb the energy of impacts to the helmet from all directions, and thereby enable the inner and intermediate liners 122 and 126 to	p. 6 "[T]he flex bumpers may be cylindrical in shape, and sized such that they engage recesses in the adjacent surfaces of the liners and middle layer, creating a space between those adjacent surfaces. The flex bumpers can flex, bend, and compress to absorb the energy of impacts from all directions, and allow the liners to move relative to the middle layer."

[6] Weber Provisional uses "flex bumpers" and "isolation dampers" interchangeably. Ex.1014[WeberProv], 3 ("The inner and outer liners engage each other to form an internal sub-assembly by the use of a plurality of flexible or elastomeric structures ***referred to herein as flex bumpers or isolation dampers***.").

move relative to each other and/or the outer liner 128."	
[0047] "The one or more recess 140 can be configured to allow for controlled lateral or rotational displacement of the inner liner 138 such that, once the inner liner 138 moves a predetermined distance relative to the outer liner 142, as indicated by the arrow in FIG. 5, the lug 136 will abut or engage one or more of the walls of the corresponding recess 140, thereby stopping movement of the inner liner 138 relative to the outer liner 142 in that direction."	p. 6, 5 "[L]ugs extending from the inner liner engage corresponding recesses in the middle layer, while lugs extending from the middle layer in turn engage corresponding recesses in the outer liner. These lugs and corresponding recesses can be designed to allow for a controlled amount of rotational movement between the liners and middle layer." "The engagement between the inner and outer liners allows for limited, controlled, omni-directional movement to reduce the transfer of forces and resulting acceleration originating from the hard outer shell of the helmet. The relative movement of the inner and outer layers is controlled via various means of suspension, dampening, and motion controlling components that engage the liners. Additional layers or partial layers may be inserted between the inner liner and the outer liner in such a way that would comprise various layers of components, with or without air gaps between them, that would allow for such controlled omni-directional relative displacement between one or more of the layers."
[0048] "In other embodiments, a similar system of lugs 136 and isolation dampers 130 can be implemented using only two layers or liners 138, 142, or alternatively, using three or more	p. 6 "In other exemplary embodiments, a similar system of lugs and flex bumpers can be implemented using only two layers, or using more than three layers. It will be readily

liners. It will be readily understood by those of skill in the art that a wide range of different configurations can be devised for the lugs 136 and isolation dampers 130 described herein. Indeed, the lugs 136 and isolation dampers 130 can take on a wide range of shapes, sizes, materials, and specific physical properties. They can also be configured to engage different layers differently than as illustrated and described herein."	understood by those of skill in the art that a wide range of potential configurations can be devised for the lugs and flex bumpers described herein. The lugs and flex bumpers may take on a wide range of shapes, sizes, materials, and specific physical properties. They may also be designed to engage different layers differently than shown herein."
[0049] "In some embodiments, the isolation dampers 130 can be configured with specific physical properties that enable them to couple an inner liner 138 with an outer layer 142 and maintain a predetermined gap therebetween, or otherwise control the spatial relationship between the two liners 138, 142. Where a space is maintained between different layers, the space can comprise an air gap, or can be completely or partially filled with any suitable material in any form, including without limitation, a liquid, gel, foam, or gas cushion."	pp. 3, 4 "The exterior shells of helmets and the corresponding interior fit padding, foam padding, air filled bladders, or other means are tasked with managing forces applied to the helmet." "Additional layers or partial layers may be inserted between the inner liner and the outer liner in such a way that would comprise various layers of components, with or without air gaps between them, that would allow for such controlled omni-directional relative displacement between one or more of the layers."
[0050] "The isolation dampers 10 enable the inner, outer and one or more intermediate layers, if any, to move omnidirectionally relative to one another, including an inner liner 104 that is in a snug, direct contact with a wearer's head most commonly via a comfort liner."	pp. 5, 7 "The engagement between the inner and outer liners allows for limited, controlled, omni-directional movement to reduce the transfer of forces and resulting acceleration originating from the hard outer shell of the helmet. The relative movement of the inner and outer layers is controlled via various means of suspension, dampening, and

	motion controlling components that engage the liners." "The inner liner may be static and engaged directly by the individual's head through the use of a comfort liner and or fit pads common in all sporting helmets." "These energy absorbing flex bumpers and lugs provide and support the ability for the component internal surfaces of the various liners and layers to be displaced and rotate in any direction necessary, independently of each other in the accident event where rotational demand forces are impacted upon the exterior of the helmet."
[0056] "[T]he method by which the isolation damper 200 is constrained and allowed to deform, or prevented from deforming, is another design technique that can be used to control the dynamic interactions of an impact force acting on a helmet and how it is transferred from one liner to another liner." "[T]he dynamic movement characteristics of the isolation dampers 200 can be managed to control and modify the ability of the outer liner 204 to move in a desired fashion in both compression and shear directions relative to the inner layer 202."	pp. 4, 6 "The liners and any other layers can be formed from materials with distinct flex, compression, and crush characteristics, and the flex bumpers can be formed from various types of elastomers or other appropriate energy absorbing materials such as micro-cellular urethane. Thus, by tuning the density and stiffness of the flex bumpers, helmets can be designed to strategically manage impact energy…." "[T]he omni-directional energy management system will allow for significant rotational shearing and omni-directional displacement to absorb energy from all force vectors."
[0062] "[T]he isolation dampers 200 can be formed of a wide variety of elastomeric materials, including MCU (micro-cellular urethane), …."	p. 6 "[T]he flex bumpers can be formed from various types of elastomers or other appropriate energy absorbing

	materials such as micro-cellular urethane."

91. Further, in my opinion, the Weber Provisional provides written-description support for at least claim 1 of Weber. In the below chart, I have summarized where each part of Weber claim 1 finds written description support in the Weber provisional. In short, based on my review of the Weber Provisional, it conveys to a person of ordinary skill in the art that the applicants of Weber had provided written description in Weber Provisional for claim 1 of Weber.

Weber (Ex.1004)	Weber Provisional (Ex.1014)
1. A helmet, comprising:	p. 4 "Another layer, the outer liner, is affixed to the hard outer shell of the helmet."
an outer shell;	
an outer liner disposed within and coupled to the outer shell; and	
an inner liner disposed within and coupled to[7] the outer liner with at least one isolation damper for omnidirectional movement of the inner liner relative to the outer liner and the outer shell.	pp. 4, 5, 6 "The inner and outer liners engage each other to form an internal sub-assembly by the use of a plurality of flexible or elastomeric structures referred to herein as flex bumpers or isolation dampers."

[7] "Coupled to", as used in Weber, has the same meaning as "connected to" and "engaged with." *See* note 55.

	"[T]he outer surface of the inner liner is connected to the inner surface of the outer liner with components that will allow for controlled omnidirectional relative displacement between the liners. Thus, the two liners are engaged with each other such that they can displace relative to each other in response to angular forces from a glancing indirect or direct blow to the hard outer shell of the helmet."

2. Claim 1

a) 1[preamble]: "A helmet comprising:"

92. Weber discloses "a helmet."

93. Weber discloses "protective helmets that protect the human head against repetitive impacts, moderate impacts and severe impacts so as to significantly reduce the likelihood of both translational and rotational brain injury and concussions." Ex.1004[Weber], [0002], Fig. 4.

b) 1[a]: "an outer shell layer;"

94. Weber discloses "an outer shell layer." Weber discloses an "**outer liner**" with "one or more additional layers or liners [that] can be inserted between an inner liner and outer liner." Ex.1004[Weber], [0045]. The outer liner (made of EPS) may be "affixed directly to the inside surface of the outer shell." Ex.1004[Weber], [0042], [0036], [0038], [0045]. The outer liner and outer shell of

Weber are an outer shell layer. I note that the '635 Patent does not define "shell," but it does state that the outer and inner "shells" "may vary in weight and strength" and "may" have certain differentiating characteristics. Ex.1001[USP635], 11:5-12. Further, these shells "may be constructed using" different materials across layers, and that set of materials include "plastics, resins, metal, composites, etc.," with "etc." recognizing that this list is non-limiting. Ex.1001[USP635], 11:5-12, 10:15-17. These statements are consistent with various layers of a helmet known to a POSA, including with the outermost layer typically including a high-strength material used to prevent penetrating forces. *Compare* Ex.1001[USP635], 11:5-12 *with* Ex.1031[Bosch], 2 (standard for different materials at outer and inner layers). Weber's outer "liner" spans the entirety of the helmet and is made of EPS, which is a type of plastic constructed from a plastic resin, specifically polystyrene resin. Ex.1004[Weber], [0036], [0038]; Ex.1049[Epsole]. Weber's outer liner thus discloses to a POSA an outer "shell layer" as used in the '635 Patent.

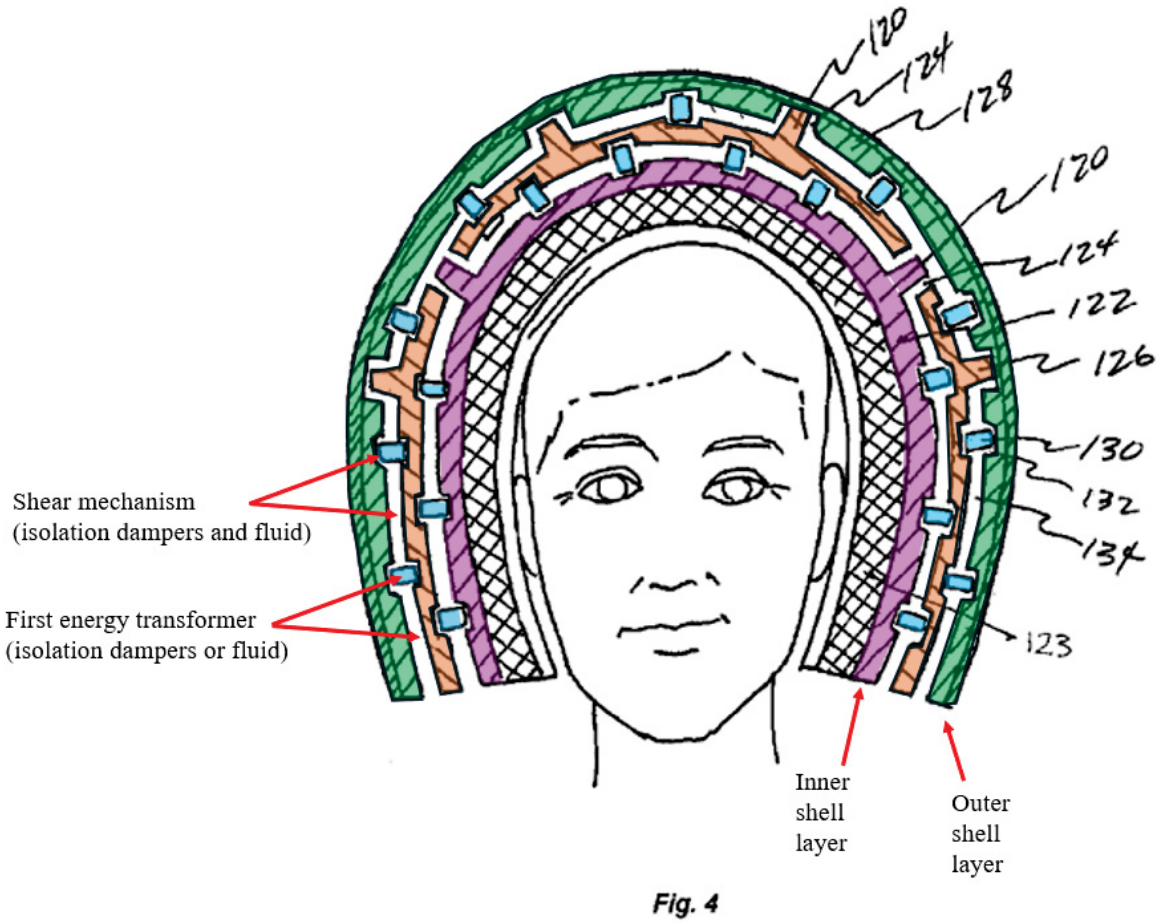


Fig. 4

Ex.1004[Weber], Fig. 4.

95. Weber equates "layers" and "liners." *See, e.g.*, Ex.1004[Weber], [0036]. To a person of ordinary skill Weber discloses its outer liner affixed to an outer shell as an "outer shell layer." Ex.1004[Weber], Figs. 2-4.

96. The specification of the '635 Patent does not describe any difference between a "shell layer," or a "layer." For example, the patent uses the terms interchangeably:

> "FIG. 6 illustrates one example of a multiple shell helmet. According to various embodiments, helmet 601 includes an outer shell layer 603, an outer energy and impact transformer 605, a middle shell layer 607, an inner energy and impact transformer 609, and **an inner shell layer** 611."

Ex.1001[USP635], 10:3-8. It also describes:

> According to various embodiments, energy and impact transformer layer 605 allows the outer shell 603 to move relative to the middle shell 607 and the energy and impact transformer layer 609 allows the outer shell 603 and the middle shell 607 to move relative to the **inner shell 611**.

Ex.1001[USP635], 10:23-27, *also compare*, Figs. 5 with 6 and 9:5-8 with 10:3-7 (describing both shells and layers with respect to same components of a helmet).

97. Therefore, the patent describes the exact same component (611) as both a "shell layer" and a "shell" –using the terms layer and shell interchangeably.

> ***c) 1[b]: "an inner shell layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material"***

98. Weber discloses "an inner shell layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material."

99. Weber discloses "an inner shell layer." Weber teaches an "**inner liner 122**" (*e.g.*, made of EPS) that moves relative to an intermediate liner 126 and/or relative to the "outer liner 128," and this inner liner is an inner shell layer. Ex.1004[Weber], [0036], [0038], [0045], Fig. 4. *See also* my discussion in Section X.A.2.b) with respect to why Weber's outer liner is a shell, which also applies to Weber's inner liner.

100. Weber also discloses that its inner liner is "connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first energy transformer." The shear mechanism is at least the components that shear and allow the outer shell layer to slide relative to the inner shell layer. In Weber, the shear mechanism includes the isolation dampers 130 and the surrounding fluid. I reproduce and annotate below Figure 4 of Weber which show **isolation dampers 130** and an air gap 134 between the **outer liner 102/128** and **inner liner 122**. Ex.1004[Weber], [0046]. Similarly, Figure 2 of Weber discloses **isolation dampers 108** and air gap disposed between **inner liner 104** and **outer layer 102**.

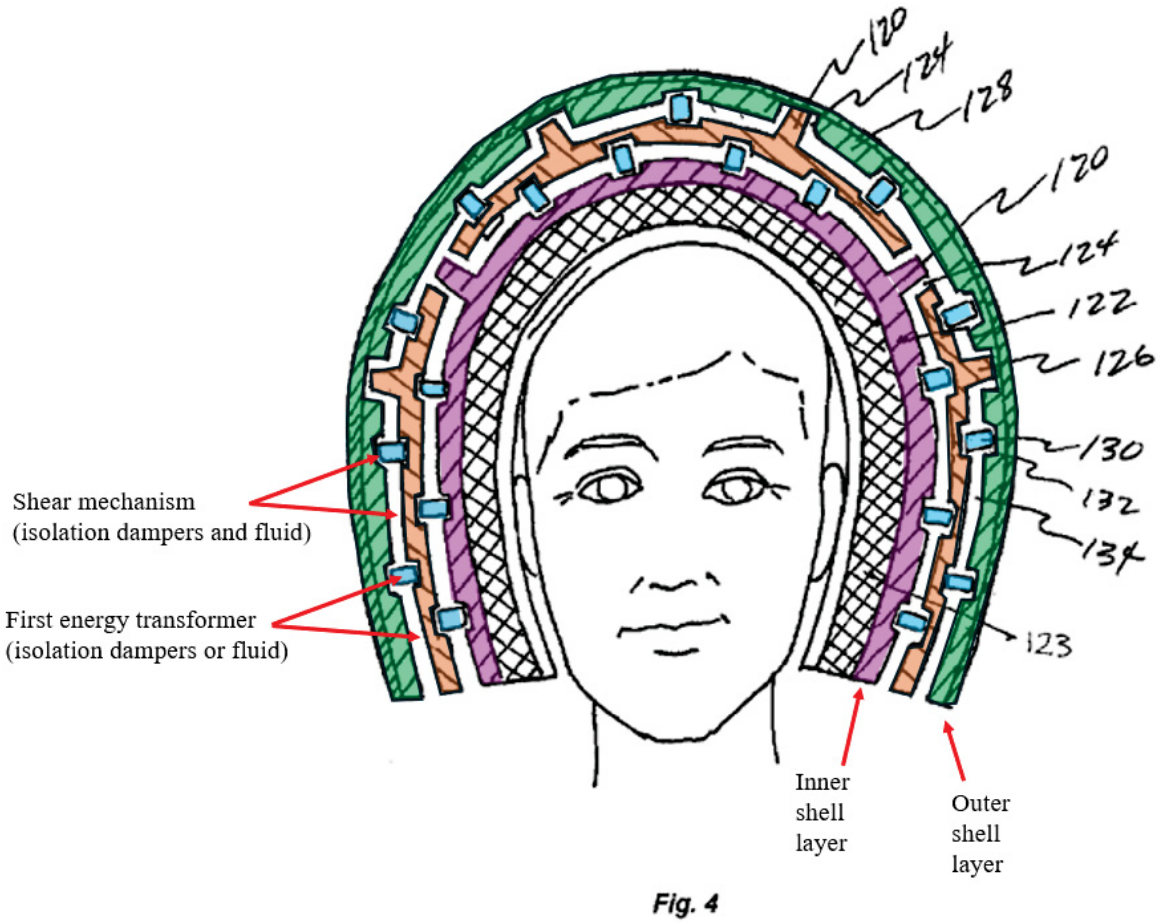
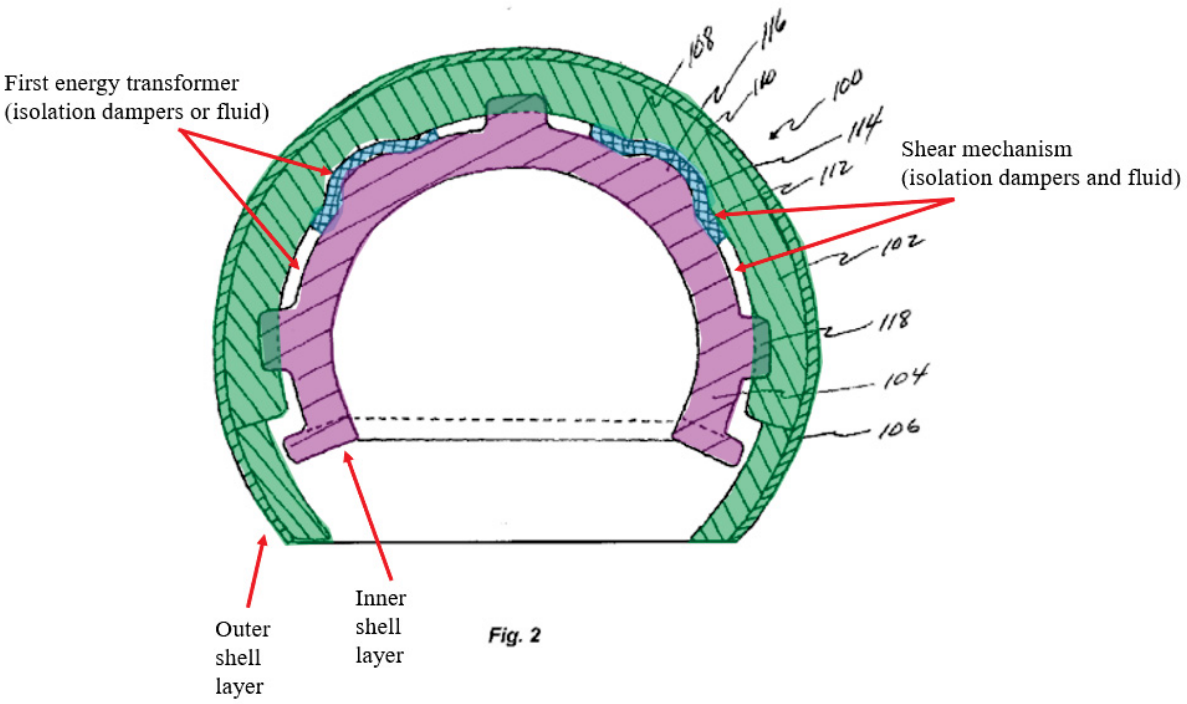


Fig. 4

Ex.1004[Weber], Fig. 4.



Ex.1004[Weber], Fig. 2.

101. Weber explains that this space can be an "air gap" or it "can be completely or partially filled with any suitable material in any form, including without limitation, a liquid, gel, foam, or gas cushion." *Id.*, [0049]. This space ("air gap") absorbs and dissipates energy from the impact force on the helmet primarily through compression, which increases internal pressure, and through displacement, which dissipates energy via resistive fluid flow, and generation of heat through these processes. The liquid, gel, foam, or gas (air is also a gas) transform energy for the same reasons as the air in the air gap. As Weber explains: "[O]mnidirectional impact energy management systems for helmets are provided that can significantly reduce

both rotational and linear forces generated from impacts imparted to the helmets." Ex.1004[Weber], [0034]. In my view, to a person of skill in the art this layer of space that is at least partially filled with fluids (*e.g.*, air) or gel absorbs and dissipates energy from the impact (on the helmet) primarily through compression, which increases internal pressure, and through displacement, which dissipates energy via resistive fluid flow, and generation of heat through these processes. Therefore, Weber discloses a layer of components (i.e. dampers and surrounding fluids/air) positioned between the outer and inner liner, which shear and allow the liners to slide relative to each other.

102. The '635 Patent specification does not use "shear mechanism" or "energy transformer." For purposes of this IPR, an energy and impact transformer encompasses an energy transformer. For example, a POSA would understand that Weber discloses a shear mechanism that includes components enabling the outer shell or liner (outer shell layer) to shear and slide relative to the inner liner (inner shell layer).

103. For example, Weber's isolation dampers "couple an inner liner [e.g.] 138 with an outer layer [e.g.] 142 and maintain a predetermined gap therebetween…." Ex.1004[Weber], [0049]. Weber also explains that the shear mechanism allows relative sliding between the shells: "The isolation dampers 130

can be configured to flex, bend, and/or compress to absorb the energy of impacts to the helmet from all directions, and thereby enable the **inner** and intermediate liners 122 and 126 **to move relative to** each other and/or the **outer liner 128**." Ex.1004[Weber], [0045]-[0046], [0050]. Thus, Weber discloses the inner liner sliding relative to the outer liner. The lateral/rotational movement of the layers in Weber's helmet is this relative sliding between the outer and inner liners and shearing is allowed by for example the isolation dampers. As the '635 patent discusses, connection may be through the shear mechanism and other layers because, "a connection between two entities does not necessarily mean a direct, unimpeded connection, as a variety of other entities may reside between the two entities." Ex.1001[USP635], 2:25-31, 10:39-44.

104. As another example, Weber states that the space in the layer can be an air gap that also facilitates relative movement between the outer and inner liners. Ex.1004[Weber], [0049], [0046]. This space enables the fluid (e.g., oil or gas) to absorb or dissipate impact energy through compression, displacement and flow, which in turn generates heat. Therefore, the shear mechanism includes isolation dampers and fluid (e.g., air).

105. Consistent with the '635 Patent (see Ex.1001[USP635], 9:11-14, 9:29-31, Fig. 5), Weber's isolation dampers and air gaps allow for relative sliding. As I

discuss in the overview of the ’635 Patent, the ’635 Patent uses the terms “move relative to” and “slide relative to” synonymously. For example, the ’635 Patent describes layers of truss structures in FIG. 5 optionally filled with fluids or gels as residing between shells and allowing them to “move and/or slide” and “allowing sliding movements. Ex.1001[USP635], 9:5-14; *see also id.*, Abstract, 2:37:41, 8:67-9:4, 9:15-24. Thus, I understand the relative sliding referred to in the ’635 Patent specification and claims as encompassing translation of one layer parallel to another or a surface, with or without direct contact between those surfaces. This understanding is consistent with how Piper used the phrase with a similar helmet structure having two layers separated by a flowable material “such as solid particulates, liquid, gel or gas.” Ex.1009[Piper], [0015], [0017], [0122]. Similarly, Weber discloses to those of ordinary skill in the art lateral/rotational movement of the layers in Weber’s helmet, allowed by isolation dampers 130, that constitutes relative sliding as the claim requires.

106. I understand that U.S. Patent No. 9,516,909 (Ex.1001[USP909]), which is in the same family as the ’635 Patent, claims a “shear mechanism” in both claim 1 and claim 11. I understand also that Claim 11 in the ’909 Patent depends from claim 1 and recites “**further comprising** a middle protective shell disposed between” the outer and inner protective shell. In my view, interpreting claim 1 in

light of claim 11 of the '909 Patent differentiates the shear mechanism from the middle protective shell. Thus, in my opinion, the shear mechanism as claimed in the '635 Patent does not include a middle protective shell.

107. In the alternative, however, and to the extent the Patent Owner argues otherwise, the shear mechanism would also be Weber's intermediate layer together with inner and/or outer dampers 130 with the surrounding air gaps in Figure 4. Ex.1004[Weber], [0045-46], Fig. 4. Weber discloses an **intermediate liner 126**[8] that is "later[ally] or rotational[ly] displace[d]" "relative to the outer liner," that is "controlled" by lugs (e.g., see lugs 120 in Figure 4 of Weber above) that engage with corresponding recesses in the outer shell. Ex.1004[Weber], [0045], [0047]. Weber's lugs can "allow for a controlled amount of rotational movement between the intermediate 126 and the inner and outer liners 122 and 128" and include "isolation dampers 130…disposed between, e.g., the inner and outer liners 122 and 128 and/or the intermediate liner 126 to further dissipate the energy of impacts." *Id.*, [0045]. This embodiment having lugs that engage in recesses in the intermediate liner "allow

[8]Weber's intermediate liner 126 is made of, for example, EPS, and is a "shell." Ex.1004[Weber], [0045]. *See* my discussion in Section X.A.2.b) with respect to Weber's outer liner, which applies in the same way to Weber's intermediate liner.

for a controlled amount of rotational movement between the intermediate 126 and the inner and outer liners 122 and 128." *Id.*, [0045]. Weber's dampers between the inner and outer liners and the intermediate liner "further dissipate the energy of impacts." *Id.* Thus, to a person of ordinary skill in the art the combination of the intermediate liner (having lugs) with the inner and outer dampers allows for relative sliding between the inner and outer liners.

108. Weber also describes the shear mechanism as including a first energy transformer that incorporates an absorptive/dissipative material. This first energy transformer is a component such as the outer **dampers 130** or the fluid filled air gap 134 in Weber's outer layer shown in Figure 4, or alternatively, **dampers 108** or the fluid-filled air gap 134 in a single layer as illustrated in Figure. 2. *Id.*, [0045]-[0046], [0039-41]. This air and dampers functions to convert the energy from an impact force into both movement and heat, which are produced through the resistive flow of fluid within the system and the mechanical deformation of the dampers, respectively. *E.g.,* Ex.1004[Weber], [0034] ("[O]mnidirectional impact energy management systems…significantly reduce both rotational and linear forces generated from impacts."); *see also* Ex.1001[USP635], 6:39-45 (fluids, gels, "absorptive/dissipative material(s)").

109. Additionally, Weber's isolation dampers and fluids are made of absorptive/dissipative materials. For example, Weber explains that the isolation dampers 130 (Figure 4) / 108 (Figure 2) "absorb the energy of impacts to the helmet from all directions," "can also be disposed between, e.g., the inner and outer liners 122 and 128 and/or the intermediate liner 126 to further **dissipate the energy of impacts**," and that they are made of resilient, "elastomeric" material. Ex.1004[Weber], [0040] ("**elastomeric**, structures referred to herein as 'isolation dampers'"); *see also id*., [0045]-[0046]. Weber also describes: "isolation dampers 200 can be formed of a wide variety of **elastomeric materials**, including MCU (micro-cellular urethane)," and can "flex, bend, and/or compress to **absorb the energy of impacts** to the helmet from all directions." Ex.1004[Weber], [0062], [0046].[9] Weber's isolation dampers 108 also comprise "a first absorptive/dissipative

[9] I note that isolation dampers 200 in Weber are exemplary isolation dampers that can be used with any embodiment of Weber, including the embodiments shown in both Figures 2 and 4 of Weber. For example, Weber discloses "isolation dampers 130", "isolation dampers 108", and "isolation dampers 200", among others. *See, e.g.,* Ex.1004[Weber], [0042]-[0043], [0045]-[0046]. To a person of skill in the art isolation dampers 200 are applicable to all embodiments of Weber.

material" because as Weber explains: "[t]he isolation dampers 108 can be made of, for example, rubber, EPU foam, or any other suitable materials that have the specific design characteristics desired in a particular application." *Id*., [0050]. To a person of ordinary skill in the art materials such as elastomeric materials, EPU foam, and others are suitable materials that are absorptive and/or dissipative.

110. Weber also discloses its air gap further absorbs and/or dissipates energy from impact force on the helmet primarily through compression, which increases internal pressure, and through displacement, which dissipates energy via resistive fluid flow, and generation of heat through these processes. As also recognized by the specification, fluids and gels are absorptive/dissipative materials. Ex.1001[USP635], 6:43-55. Air is a type of fluid. Therefore, in my opinion, Weber's isolation dampers disclose the "first energy transformer having a first absorptive/dissipative material."

d) 1[c]: "the inner shell layer configured to conform to a human head;"

111. Weber discloses "the inner shell layer configured to conform to a human head." Weber teaches that its "inner liner" can be "disposed in contact with the wearer's head, either directly or via a fitment or so-called 'comfort liner.'" Ex.1004[Weber], [0036]; *see also id.*, [0045], [0050]. The **inner liner 122**

conforming to a human head is depicted in purple in Figures 2 and 4, reproduced below:

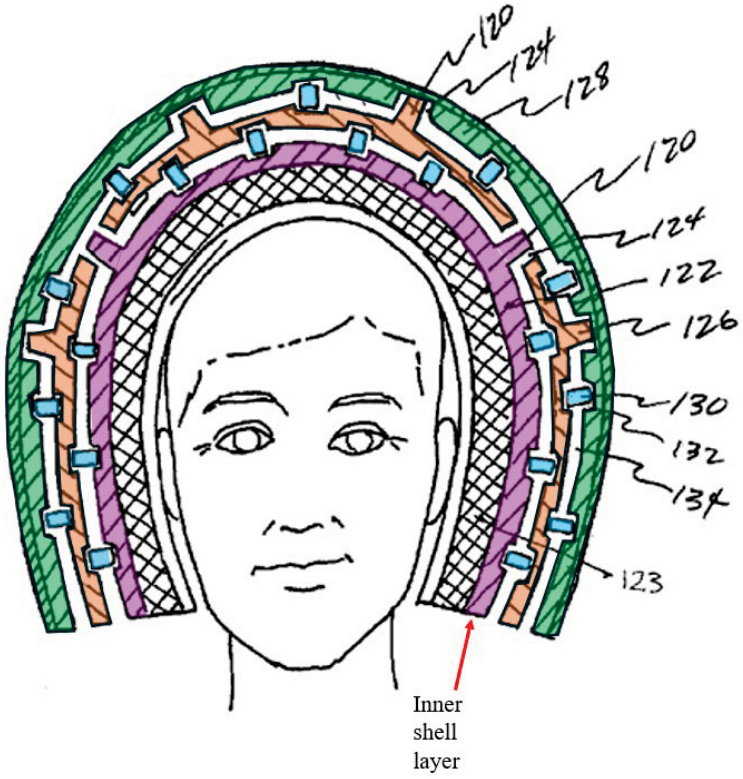


Fig. 4

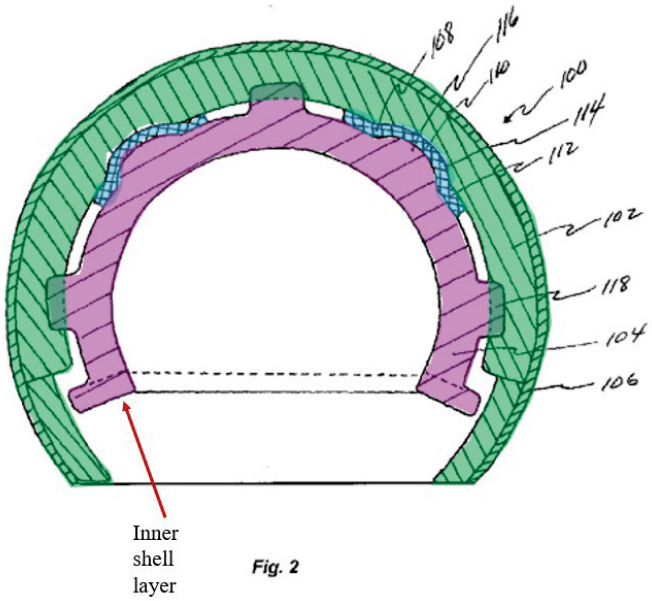


Fig. 2

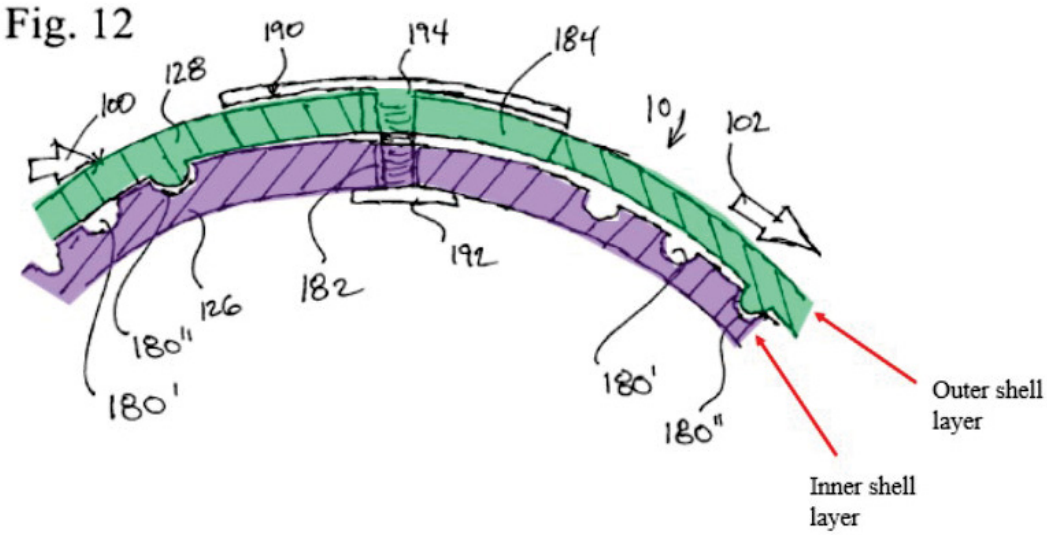
Ex.1004[Weber], Figs. 2, 4.

e) 1[d]: "a chin strap attached to the inner shell layer to maintain the position of the inner shell layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

112. Weber combined with Puchalski renders obvious "a chin strap attached to the inner shell layer to maintain the position of the inner shell layer on the human head during rotational force impact while the outer shell layer is allowed to slide." In my opinion, a person of skill in the art would have found it obvious to use the location of Puchalski's chin-strap for Weber's chin-strap in Weber's helmet. In the embodiments of Weber, "[p]roper restraint on the wearer's head can be managed by, for example, a **chin-strap** and/or a neck security device of a type commonly used on conventional helmets." Ex.1004[Weber], [0038]. As discussed for limitation 1[c]

(see my discussion above in Section X.A.2.d), Weber's inner liner is "configured to closely surround the head of the wearer." Ex.1004[Weber], [0045], *see also id.*, [0036], [0050]. Weber does not explicitly discuss where within the helmet its "chin-strap" is attached.

113. Like Weber, Puchalski describes a helmet "as including a generally two-part dome shaped shell 14 which includes a **separate and distinct inner dome-shaped panel 126** and an **outer dome-shaped panel 128**." Ex.1011[Puchalski], 11:36-39. Consistent with Weber's teachings, Puchalski also states that, "upon the application of a predetermined minimum impact force (Arrow 100) on the outer panel 128, the impact force results in the sliding movement of the outer panel 128 relative to the inner panel 126":



Ex.1011[Puchalski], 12:55-58, Fig. 12.

114. Puchalski explains that "[a]lthough not essential, most preferably, the helmet chin straps 16 are secured to the peripheral edge of the inner panel 126, along each of its sides." Ex.1011[Puchalski], 12:1-3, *see also id*., 7:26-27 ("The **chin-strap 16** is of a conventional two-piece design and is secured at each of its ends …."). Figs. 9-10, which I reproduce below, depict this configuration of elements:

Fig. 9

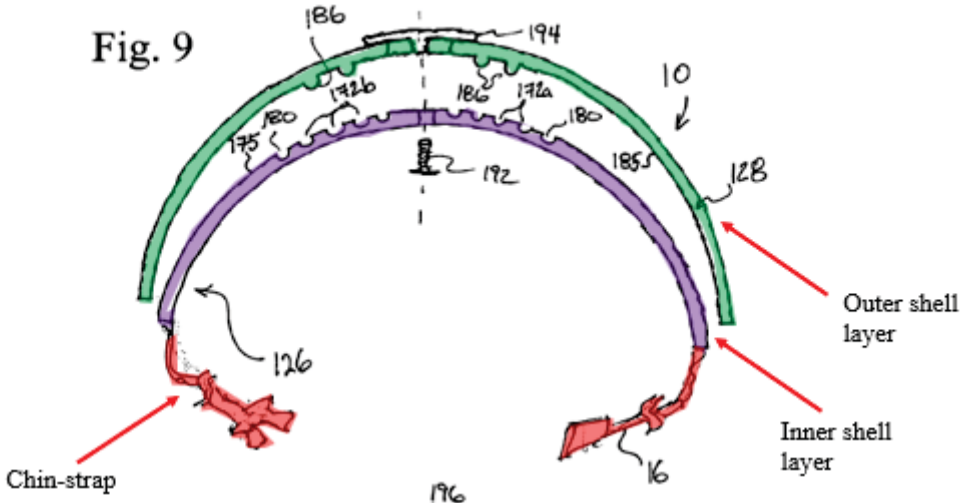
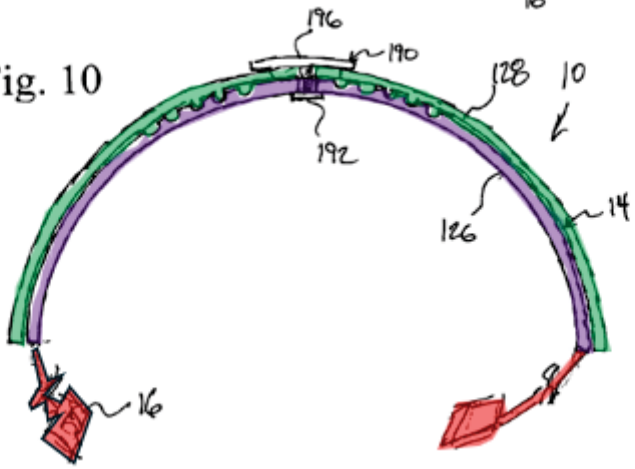


Fig. 10



Ex.1011[Puchalski], Figs. 9-10.

115. In my opinion, a personal of ordinary skill in the art would have been motivated, with a reasonable expectation of success, to attach Weber's "chin-strap"

in Weber's helmet at a location corresponding to the location of the chin-strap in Puchalski (*i.e.*, to Weber's inner liner). It is my understanding that Weber and Puchalski are considered analogous art to the challenged claims and this is because they are both in the same field of helmet design and are directed to the same problem (as that in the '635 Patent claims) of addressing rotational impact and use the same solution of improving helmet design by using multiple sliding layers. In my view, both Weber and Puchalski disclose to a person of skill in the art using a chin-strap to maintain a proper position of the helmet on the person wearing it.

116. Puchalski teaches that the best place to attach the chin-strap is on an inner layer that slides relative to an outer layer, which is optional for maintaining the position of the inner layer relative to the wearer's head. In my opinion, the obvious design choice to a person of skill in the art would have been to place the chin-strap on the inner layer because the purpose of the chin-strap is to secure the helmet for "[p]roper restraint on the wearer's head". The inner layer allows the helmet to conform to the wearer's head and ensure that the helmet stays attached while at the same time allowing the outer layer to slide upon rotational impact, as I discussed for limitation 1[b] (see my discussion in Section X.A.2.c; *see also* Ex.1041[Dotsuko], [0022]; *see also* Ex.1047[Madey], [0025]). In my view, while there would have been a small and very finite set of other options of where to attach the chin-strap on

the helmet, these other options were less desirable. For example, if the chin-strap were attached to another movable layer (*e.g.*, the outer layer) with the inner layer still conformed to the wearer's head, then movement of that other movable layer (*e.g.*, the outer layer) would cause movement of the chin-strap as well. This situation could be uncomfortable to the user (*e.g.*, by displacing the outer layer from its proper position) and/or could result in the chin-strap no longer securing the helmet to the wearer's head. Additionally, to a person of ordinary skill in the art attaching the chin-straps to the inner liners of a helmet also ensures proper and consistent fit with the wearer's head. For example, when the chin-strap is attached to the inner layer, it will be closer and more snug with a wearer's face/chin area to ensure a tight/proper fit, whereas if it were attached to a different and more outer layer, the chin-strap would naturally be further removed from the chin/face of the wearer (at least in more lateral positions of the strap) due to the thickness of the entire helmet itself. A person of skill in the art would therefore find it most natural and logical to attach the chin-strap to the inner layer.

117. In addition, there is a limited number of solutions – Weber's "chin-strap" has a finite number of places to which it can be attached. It has to be attached to one of the shell layers or liners (i.e., a structural helmet feature), and there are only three possible layers/liners in Weber: (1) the inner layer, (2) the intermediate

layer, or (3) the outer layer.[10] (In the Figure 2 embodiment, there are only two options: the inner and outer layer.) In my view, a person of ordinary skill in the art would have been motivated to try each of these limited options but, as I discussed above in this section, would have been most motivated to attach the chin-strap in Weber's helmet to the inner layer based on Puchalski's inner layer position to ensure a proper, secure, and consistent fit of the strap and thus the helmet as well.

118. In my opinion, a person of skill in the art would have had a reasonable expectation of success in modifying Weber's helmet and "chin-strap" with the location of Puchalski's chin-strap. In my opinion, POSAs are more than capable of modifying the location of a chin-strap to suit specific helmet designs. For example, a POSA would have known how to select an appropriate chin-strap location and implement that solution, for example, so that the outer layer of a helmet has

[10] I note that to the extent Weber's damper layers are considered a possible attachment location (which they aren't), a POSA would not have attached a chin-strap to these layers because this would interfere with the functionality of the dampers (e.g., providing a dampening effect) and would also not provide for a secure attachment because the space between the dampers is filled with air/liquid/gas.

sufficiently strong connections to the rest of the helmet to ensure integrity of the system even without chin-strap attachments. As I discuss above in this section, Weber teaches a chin-strap attached to its helmet and while it doesn't say where that chin-strap is placed, a person of ordinary skill in the art would have been able to attach the chin-strap to the inner shell layer of Weber's helmet, simply as a matter of routine implementation. At the time, by 2011, it was conventional to attach chin-straps to the inner layer of helmets (*i.e.*, layers that conformed to the wearer's head). Ex.1041[Dotsuko], [0018], [0022]; Ex.1047[Madey], [0025]; Ex.1043[Field], 2:51-52, 5:48-51; Ex.1032[Mills-2006], 169; Ex.1044[Copeland], Fig. 3; Ex.1045[Noniyama], 2:30-31, 2:14-16; Ex.1046[Goldman], 1:19-32. The '635 Patent's specification further supports the fact that this was conventional, as it identifies no design challenges which were overcome or that would have otherwise caused difficulty in attaching the chin-strap at this location. Ex.1001[USP635], 10:3-38.

119. Thus, in my opinion, claim 1 is obvious over Weber combined with Puchalski.

3. Claim 2

a) "The helmet of claim 1, wherein the shear mechanism is a shear layer."

120. Weber combined with Puchalski renders claim 1 obvious. *See* my discussion above in Section X.A.2 which I incorporate here. Weber also teaches that the shear mechanism (which includes Weber's isolation dampers and fluid) is "a shear layer." As discussed for element 1[b] (*see* my discussion in Section X.A.2.c), Weber has a layer of isolation dampers with, for example, air between the inner and outer liners. For example, in Figure 4 of Weber, the outer isolation dampers 130 form a layer of dampers that may contain a fluid such as air or a liquid. Ex.1004[Weber], [0046], [0049], Fig. 4; *see also* my discussion in Section X.A.2.c). Likewise, if the shear mechanism also includes the intermediate liner in Weber, then the "shear layer" is made up of both the intermediate liner and one or both surrounding layers of dampers 130 in Figure 4. Likewise, in Figure 2 of Weber, the isolation dampers 108 form a shear layer. Ex.1004[Weber], Fig. 2; *see also* my discussion in Section X.A.2.c)X.A.2.d). With respect to both Figures 2 and 4 of Weber, a person of ordinary skill in the art would immediately appreciate that the shear mechanism of Weber is a shear layer (the dampers are arranged as a distinct layer, with or without including the intermediate liner as well).

121. Thus, in my opinion, claim 2 is obvious over Weber combined with Puchalski.

4. Claim 3

a) "The helmet of claim 2, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer."

122. Weber combined with Puchalski renders obvious claim 2. *See* my discussion above in Section X.A.3 which I incorporate here. Weber teaches "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer."

123. I note that the '635 Patent explains that "a connection between two entities does not necessarily mean a direct, unimpeded connection, as a variety of other entities may reside between the two entities." Ex.1001[USP635], 2:25-28. It also describes that "connections" may be "indirect" (*i.e.*, "through" an energy and impact transformer) or layers may be "loosely connected." *See, e.g.*, Ex.1001[USP635], 8:45-48; 10:39-41. To a person of ordinary skill in the art Weber's shear layer (*i.e.*, layer of dampers and fluid/air, or combination of dampers and fluid/air with intermediate liner, *see* my discussion in Section X.A.2.d)) is

connected to the outer shell layer (*i.e.*, outer liner) through a "first energy transformer."

124. As discussed above, the "shear layer" is the layer of dampers and the layer of fluid (potentially with the intermediate liner). The "first energy transformer" in Weber is the damper/layer of dampers or fluid. Ex.1004[Weber], [0036], [0037], [0046], [0049], Fig. 2, Fig. 4.

125. **First**, the dampers are a first energy transformer. As can be seen above in annotated Figure 4 of Weber, in this case, the shear layer is the **dampers 130** and layer of fluid/air. The **dampers 130** allow the shear layer to be connected to the **outer shell layer** through the first energy transformer.

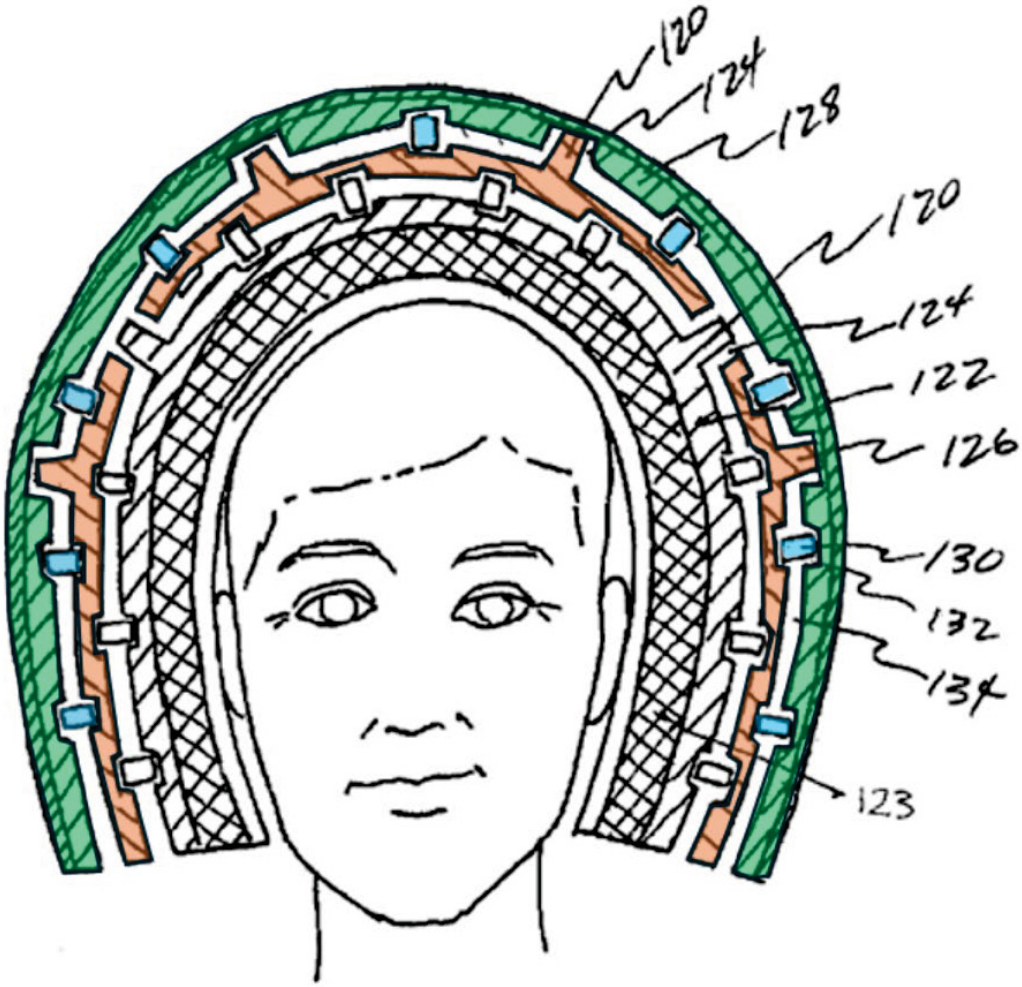
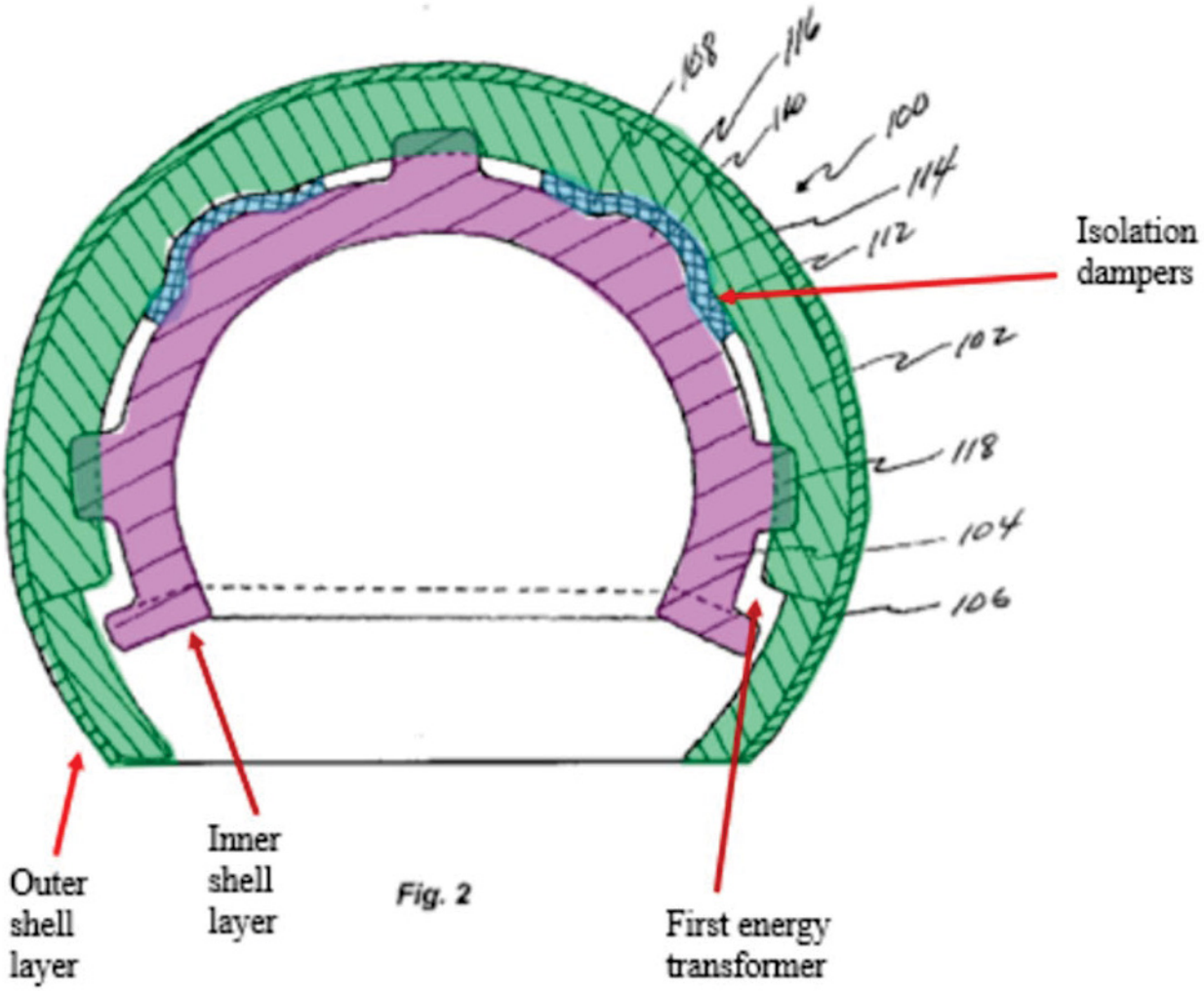


Fig. 4

Ex.1004[Weber], FIG. 4.

126. Likewise, as shown in Figure 2 of Weber, **dampers 108** are a first energy transformer and allow the shear layer to be connected to the **outer shell layer** through the first energy transformer.



Ex.1004[Weber], FIG. 2.

127. Weber's first energy transformer (dampers) includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer. I discuss this in Section X.A.3, which I incorporate here.

128. **Second**, the the space or air gap filled with air or other fluid between Weber's dampers is a first energy transformer. In Figure 4 of Weber shown below, the shear layer is the later **dampers 130** (optionally with fluid/air in between). The

space or air gap filled with air or fluid between **dampers 130** is a first energy transformer and this allows the shear layer to be connected to the **outer shell layer** through the first energy transformer.

129. Likewise, Figure 2 of Weber (which I annotate above) which shows that the first energy transformer as the space or air gap filled with air or fluid between **dampers 108** that allows the shear layer (**dampers 108** with or without fluid/air) to be connected to the **outer shell layer** through the first energy transformer.

130. In the case that Weber's first energy transformer is the space or air gap filled (or partially filled) with air or fluid, it includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer. Ex.1004[Weber], [0045], [0046], [0050]. The specification of the '635 Patent explains that fluids/air/gel are absorptive/dissipative materials: "For example, a smart fluid may change from a liquid to a gel when magnets line up to create a magnetic field. Smart fluids may react within milliseconds to reduce impact and shear forces between shells." Ex.1001[USP635], 6:60-63. A person of ordinary skill in the art would have also understood that air is an absorptive/dissipative material because it absorbs and dissipates impact force through movement. Air/fluid in Weber absorbs and dissipates impact energy primarily through compression,

which increases internal pressure, and through displacement, which dissipates energy via resistive fluid flow, and generation of heat through these processes.

131. Thus, in my opinion, claim 3 is obvious over Weber combined with Puchalski.

5. Claim 4

a) "The helmet of claim 3, wherein the inner shell layer is connected to the shear layer, the inner shell layer configured to conform to a human head, the inner shell layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer."

132. Weber combined with Puchalski renders obvious claim 3. *See* my discussion above in Section X.A.4 which I incorporate here. Weber also teaches that "the inner shell layer is connected to the shear layer, the inner shell layer configured to conform to a human head, the inner shell layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer."

133. Weber teaches "one or more additional layers or liners can be inserted between an inner liner and outer liner. Such 'intermediate' liners can be formed of,

for example, EPS…, or any other suitable materials." Ex.1004[Weber], [0045], *see also id.*, [0038] (explaining that any layer of Weber can be formed of EPS). This inner liner is an inner shell layer as discussed in Section X.A.2.c. For example, I show below an annotated version of Figure 4 of Weber which depicts **an inner liner** (the inner shell layer) and an intermediate liner 126. Weber also teaches an additional layer of **isolation dampers** and air gaps between the inner liner and intermediate liner: "Optionally, in some embodiments, **isolation dampers 130** of various configurations can also be ***disposed between***, e.g., **the inner** and outer liners 122 and 128 and/or the intermediate liner 126 to further dissipate the energy of impacts." Ex.1004[Weber], [0045]. Figure 4 below shows the isolation dampers between the inner liner and the intermediate liner 126. As I discussed in Section X.A.2.c), and as seen in Figure 4 below, there is an "air gap" (or gap with another fluid) between the dampers (for both the outer and inner dampers). Ex.1004[Weber], [0046], Fig. 4. Weber explains that this layer of space can be an "air gap" or other materials. *Id.*, [0049]; *see also id.*, [0038], [0045]-[0046], Fig. 4. Weber's "second energy transformer" is the dampers or fluid (e.g., air). Further, Weber discloses "the second energy transformer including a second absorptive/dissipative material." For example, Weber teaches that its isolation dampers "further dissipate the energy of impacts." Ex.1004[Weber], [0045]; *see*

also Section X.A.2. Weber also explains that the fluid (air) absorbs and dissipates energy from the impact force on the helmet primarily through compression, which increases internal pressure, and through displacement, which dissipates energy via resistive fluid flow, and generation of heat through these processes. This way in which energy from impacts is absorbed and/or dissipated similarly applies to Weber's disclosure that the space "can be completely or partially filled with any suitable material in any form, including without limitation, a liquid, gel, foam, or gas cushion." Ex.1004[Weber], [0049]. Weber discloses that its helmet enables "controlled, omnidirectional relative movement," which helps reduce forces transmitted "from the hard outer shell of the helmet to the head and brain of a wearer." Ex.1004[Weber], [0037]; *see also id*., [0008] (helmet designed to 'reduce' impact transferred to the brain). Accordingly, Weber indicates that some forces originating from the outer shell are transmitted to the second energy transformer, which would absorb energy in the same way as the first energy transformer.

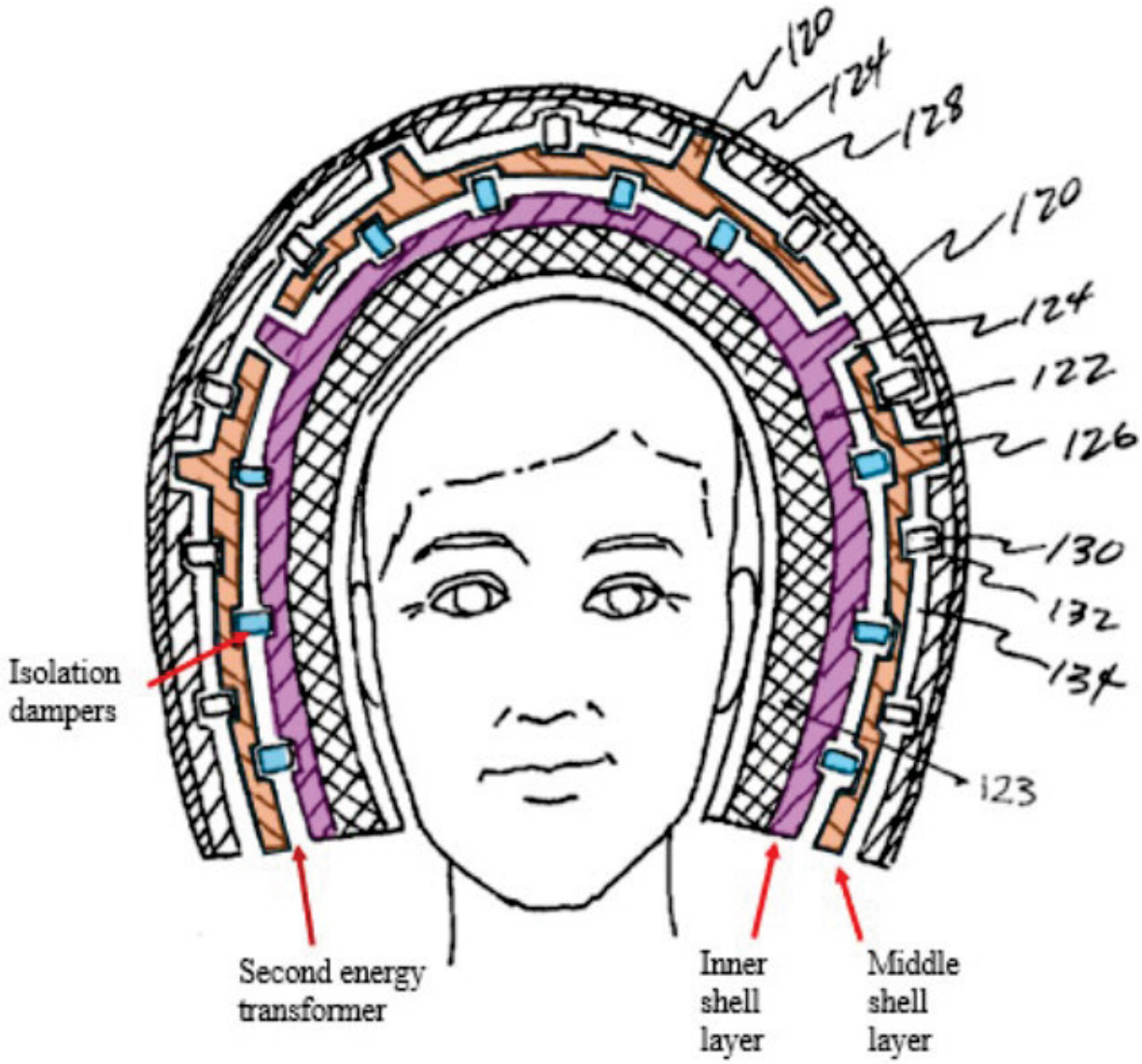


Fig. 4

Ex.1004[Weber], FIG. 4.

134. Thus, in my view, claim 4 is obvious based on Weber combined with Puchalski.

6. Claim 6

a) "The helmet of claim 1, wherein the first absorptive/dissipative material comprises a fluid."

135. Weber combined with Puchalski renders obvious claim 1. *See* my discussion above in Section X.A.2 which I incorporate here. Weber teaches "the first absorptive/dissipative material comprises a fluid" for the same reasons that I discussed above in Section X.A.2. For example, Weber explains that the gap between the outer and intermediate liners (and surrounding the dampers) "can be completely or partially filled with any suitable material in any form, including without limitation, a liquid, gel, foam, or gas cushion." Ex.1004[Weber], [0049]. This same disclosure applies to the gap between the inner and intermediate liners (and surrounding the dampers).

136. Therefore, it is my view, claim 6 is obvious based on Weber combined with Puchalski.

7. Claim 8

a) "The helmet of claim 1, wherein a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head."

137. Weber combined with Puchalski renders obvious claim 1. *See* my discussion above in Section X.A.2 which I incorporate here. Weber teaches "a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head." Weber teaches coupling its "inner liner" (inner shell layer, see Fig. 4 of Ex.1004 discussed in Section X.A.2.d)) at its inner surface to "a

'comfort' liner 123 configured to closely surround the head of the wearer." Ex.1004[Weber], [0045], *see also id.*, [0036], [0050]. This **comfort liner 123** between the inner shell layer and the human head is shown in Figure 4 of Weber which I reproduce and annotate below:

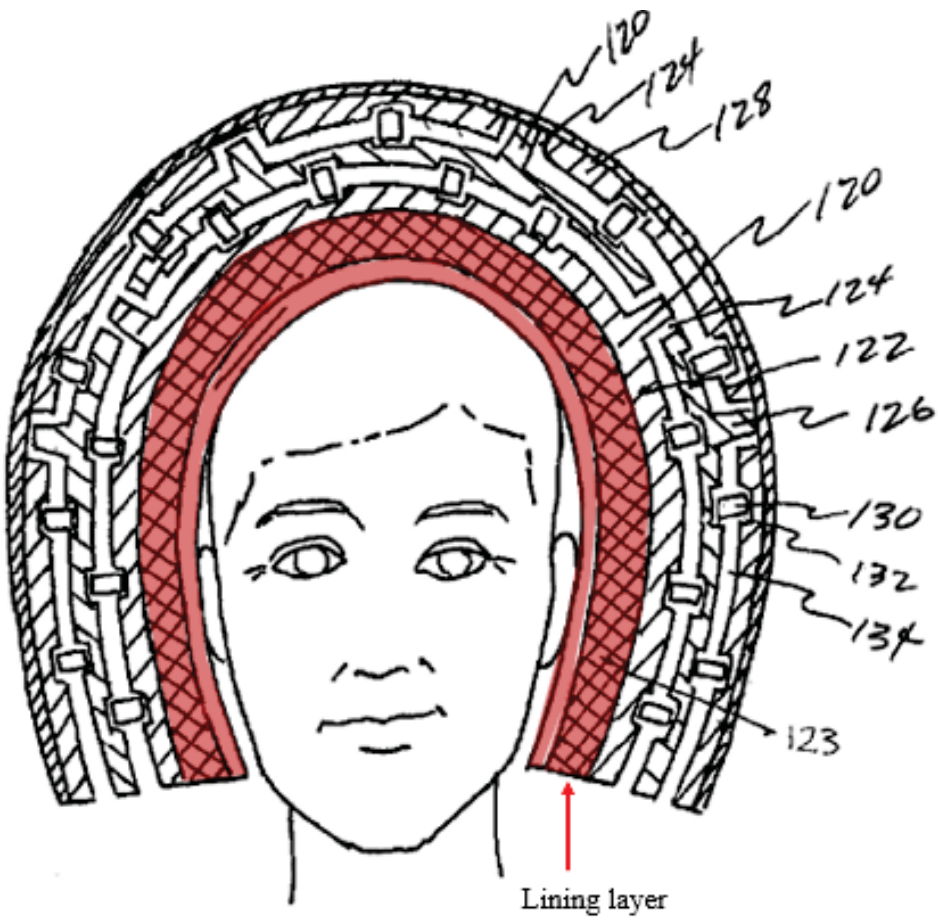


Fig. 4

Ex.1009[Weber], Fig. 4.

138. Therefore, it is my view, claim 8 is obvious based on Weber combined with Puchalski.

8. Claim 9

a) 9[preamble]: "Protective gear comprising:"

139. Weber discloses a "helmet" such as "protective helmets." Ex.1004[Weber], [0002]. As shown in a helmet embodiment in Figure 2 of Weber, which I reproduce and annotate below, this helmet has inner liner 104, outer liner 102 affixed directly to "shell 106", and a layer of isolation dampers 108 with air gaps connecting the inner and outer liners.

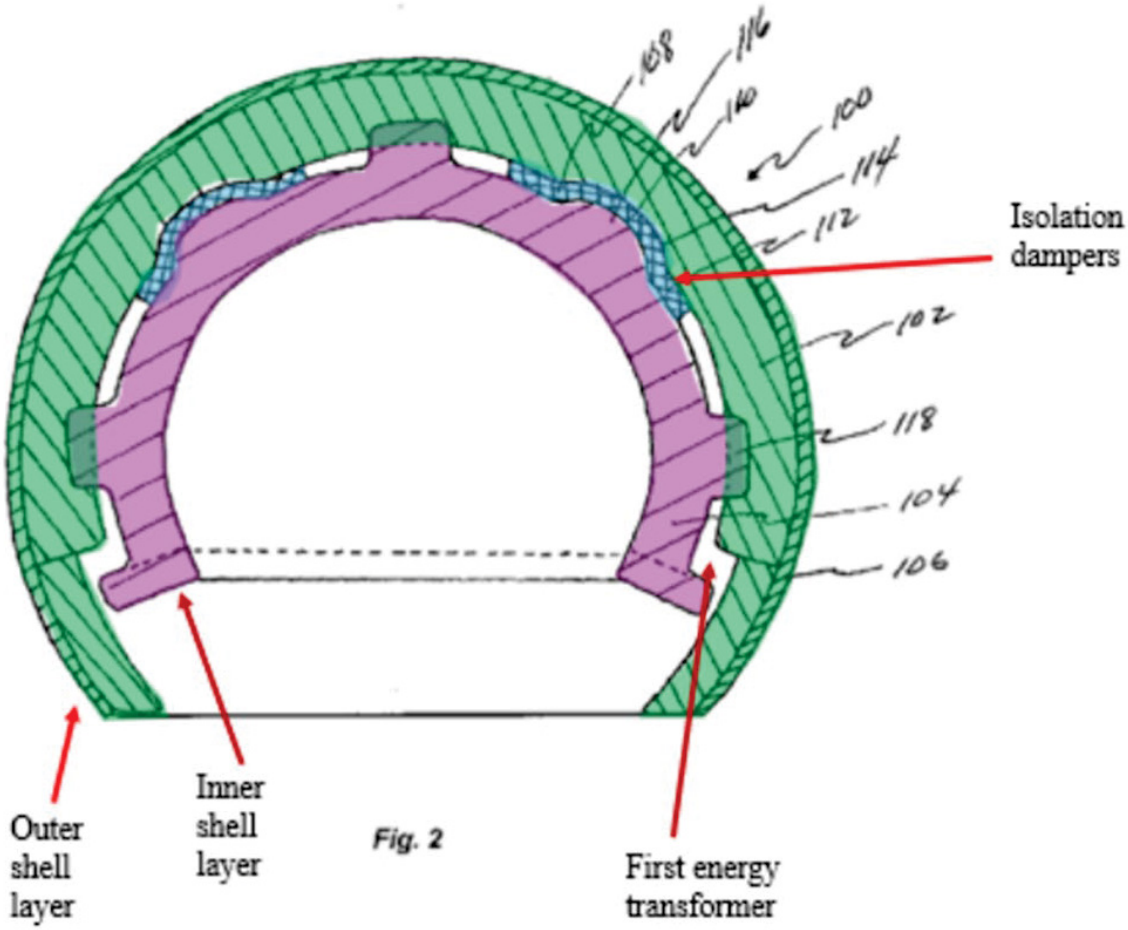


Fig. 2

Ex.1004[Weber], Fig. 2.

b) 9[a]: "an outer shell layer;"

140. In my opinion, Weber discloses "an outer shell layer" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.A.2.b). Specifically, as shown in Figure 2 below, Weber discloses "outer liner 102" "inside of" and "attached directly to" "relatively hard helmet outer shell 106." Ex.1004[Weber], [0039], Fig. 2. Weber's "outer shell layer" is the outer liner 102 affixed to the outer shell 106.

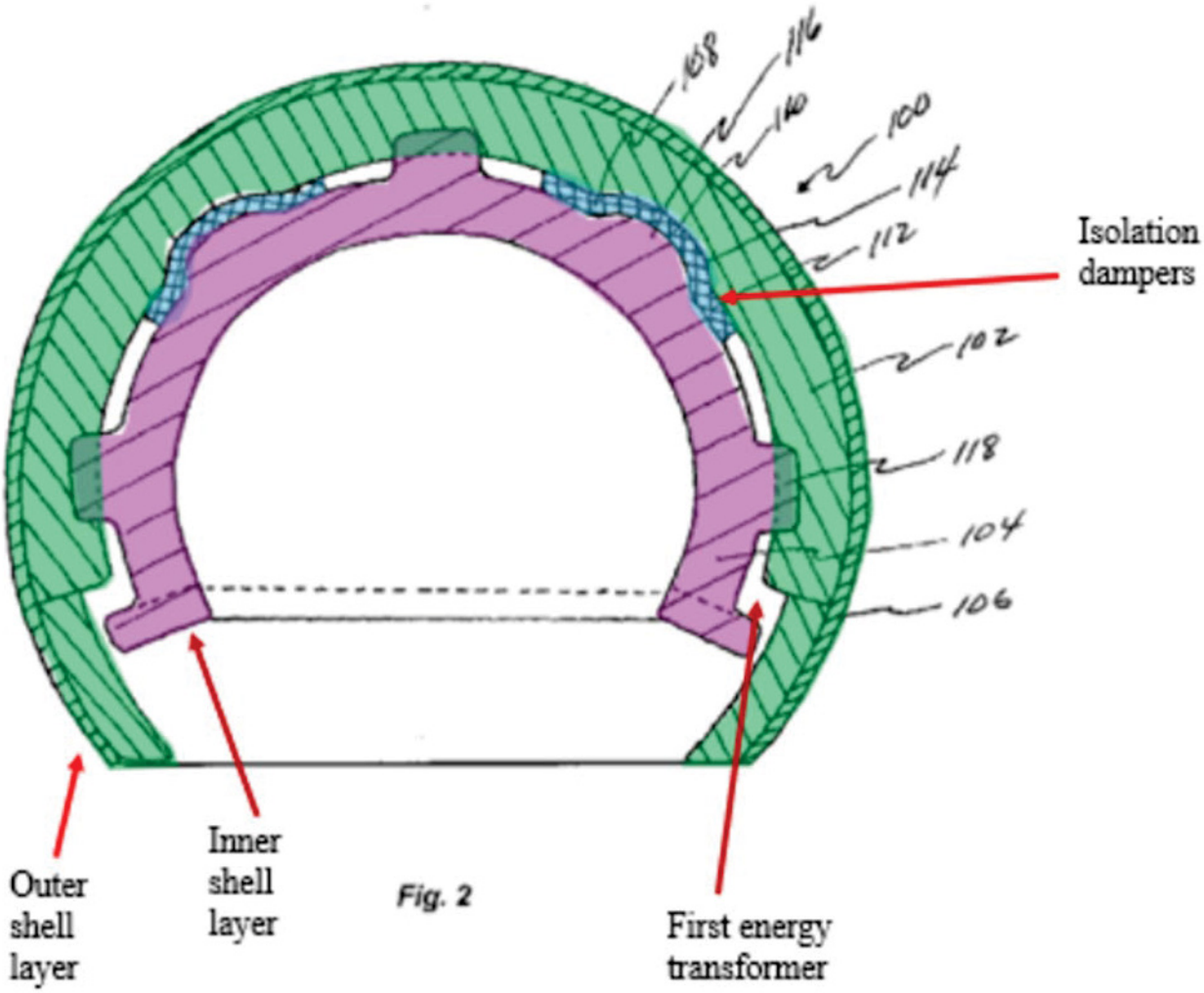


Fig. 2

Ex.1004[Weber], Fig. 2, [0039-40].

c) 9[b]: "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

141. In my opinion, Weber discloses "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes

a first energy transformer having a first absorptive/dissipative material" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.A.2.c). I note that the "inner conforming layer" in claim 9 is encompassed within the "inner shell layer" in claim 1. Specifically, claim 1 describes that its "inner shell layer" is "configured to conform to a human head," making the inner shell layer also an "inner conforming layer." Consistent with this understanding, claim 9 similarly states its "inner conforming layer" is "configured to conform to a human head." The '635 Patent's specification does not describe "conforming layer" or "conform" anywhere except the claims, and it does not provide any other discussion that would alter my understanding. To the extent there is any difference between "inner shell layer" and "inner conforming layer", in my view, both inner shell layer and inner conforming layer are taught by Weber.

d) 9[c] "the inner conforming layer configured to conform to a human head;"

142. In my opinion, Weber discloses "the inner conforming layer configured to conform to a human head" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.A.2.d).

e) 9[d]: "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

143. In my opinion, Weber combined with Puchalski discloses "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.A.2.e).

144. For all of the reasons discussed above, it is my view that claim 9 is obvious over Weber combined with Puchalski.

9. Claim 10

a) "The protective gear of claim 9, wherein the shear mechanism is a shear layer."

145. Weber combined with Puchalski renders claim 9 obvious. Section X.A.8. Weber discloses "the shear mechanism is a shear layer." Specifically, Weber discloses claim 10 for the same reasons as I discussed above with respect to claim 2. *See my* discussion in Section X.A.3 above, which I incorporate here.

146. Therefore, in my view, claim 10 is obvious over Weber combined with Puchalski.

10. Claim 11

a) "The protective gear of claim 10, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first

absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer."

147. Weber combined with Puchalski renders claims 10 obvious. Section X.A.9. Weber discloses "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer." Specifically, Weber discloses claim 11 for the same reasons as I discussed above with respect to claim 3. *See my* discussion in Section X.A.4 above, which I incorporate here.

148. Therefore, in my view, claim 11 is obvious over Weber combined with Puchalski.

11. Claim 12

a) "The protective gear of claim 11, wherein the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer."

149. Weber combined with Puchalski renders claim 11 obvious. Section X.A.10. Weber discloses "the inner conforming layer is connected to the shear layer,

the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer." Specifically, Weber discloses claim 12 for the same reasons as I discussed above with respect to claim 4. *See my* discussion in Section X.A.5 above, which I incorporate here.

150. Therefore, in my view, claim 12 is obvious over Weber combined with Puchalski.

12. Claim 14

a) "The protective gear of claim 9, wherein the first absorptive/dissipative material comprises a fluid."

151. Weber combined with Puchalski renders claim 9 obvious. Section X.A.8. Weber discloses "the first absorptive/dissipative material comprises a fluid." Specifically, Weber discloses claim 14 for the same reasons as I discussed above with respect to claim 6. *See my* discussion in Section X.A.6 above, which I incorporate here.

152. Therefore, in my view, claim 14 is obvious over Weber combined with Puchalski.

13. Claim 16

a) "The protective gear of claim 9, wherein the inner conforming layer is associated with a lining material configured to conform to a human head."

153. Weber combined with Puchalski renders claim 9 obvious. Section X.A.8. Weber discloses "the inner conforming layer is associated with a lining material configured to conform to a human head." Specifically, Weber discloses claim 16 for the same reasons as I discussed above with respect to claim 8. *See my* discussion in Section X.A.7 above, which I incorporate here.

154. Therefore, in my view, claim 16 is obvious over Weber combined with Puchalski.

14. Claim 17

a) 17[preamble]: "A helmet comprising:"

155. In my opinion, Weber discloses "[a] helmet" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.A.2.a) and X.A.8.a).

b) 17[a]: "an outer shell layer;"

156. In my opinion, Weber discloses "an outer shell layer" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.A.2.b) and X.A.8.b).

c) 17[b]: "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming

layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

157. In my opinion, Weber discloses "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.A.2.c) and X.A.8.c).

d) 17[c] "the inner conforming layer configured to conform to a human head;"

158. In my opinion, Weber discloses "the inner conforming layer configured to conform to a human head" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.A.2.d) and X.A.8.d).

e) 17[d]: "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

159. In my opinion, Weber combined with Puchalski discloses "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.A.2.e) and X.A.8.e).

160. For all of the reasons discussed above, it is my view that claim 17 is obvious over Weber combined with Puchalski.

15. Claim 18

a) "The helmet of claim 17, wherein the shear mechanism is a shear layer."

161. Weber combined with Puchalski renders claim 17 obvious. Section X.A.14. Weber discloses "the shear mechanism is a shear layer." Specifically, Weber discloses claim 18 for the same reasons as I discussed above with respect to claims 2 and 10. *See my* discussion in Sections X.A.3 and X.A.9 above, which I incorporate here.

162. Therefore, in my view, claim 17 is obvious over Weber combined with Puchalski.

16. Claim 19

a) "The helmet of claim 18, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer."

163. Weber combined with Puchalski renders claim 18 obvious. Section X.A.15 Weber discloses "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy

from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer." As I discussed above, Weber discloses claim 19 for the same reasons as claims 3 and 11. *See* my discussion in Sections X.A.4 and X.A.10.

164. Therefore, it is my view that claim 19 is obvious over Weber combined with Puchalski.

17. Claim 20

a) "The helmet of claim 19, wherein the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer."

165. Weber combined with Puchalski renders claim 19 obvious. Section X.A.16 Weber discloses "the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer

through the outer shell layer and the first energy transformer". As I discussed above, Weber discloses claim 20 for the same reasons as I provided with respect to claims 4 and 12. *See* my discussion above in Sections X.A.5 and X.A.11.

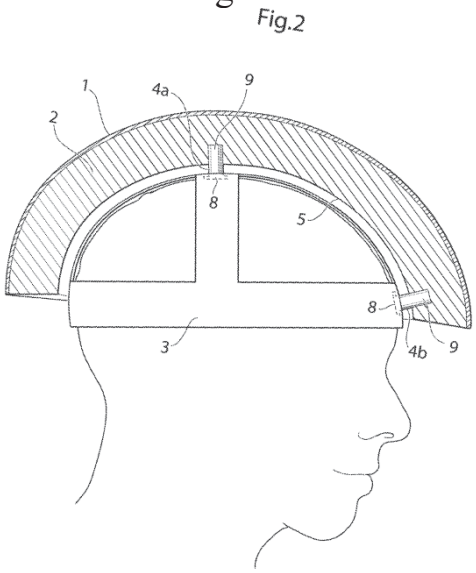
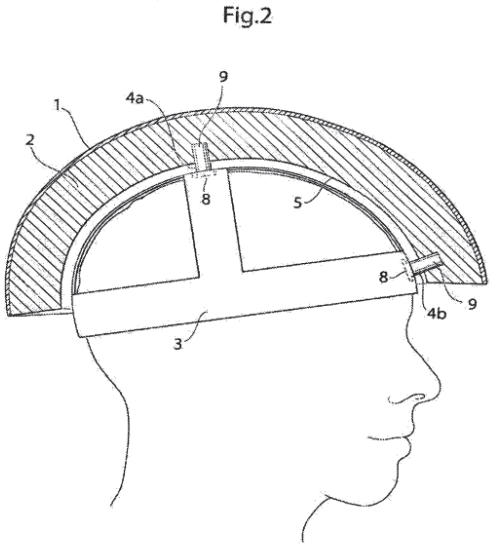
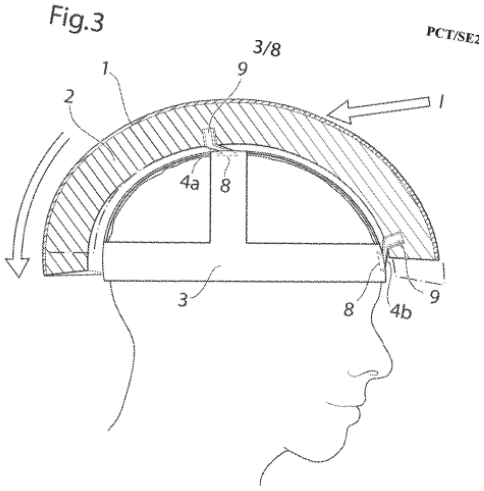
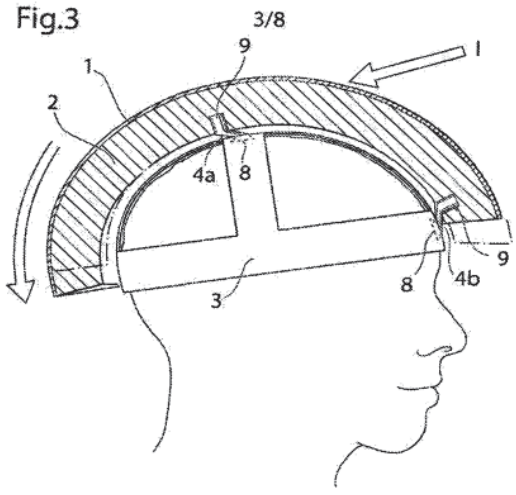
166. Therefore, it is my opinion that claim 20 is obvious over Weber combined with Puchalski.

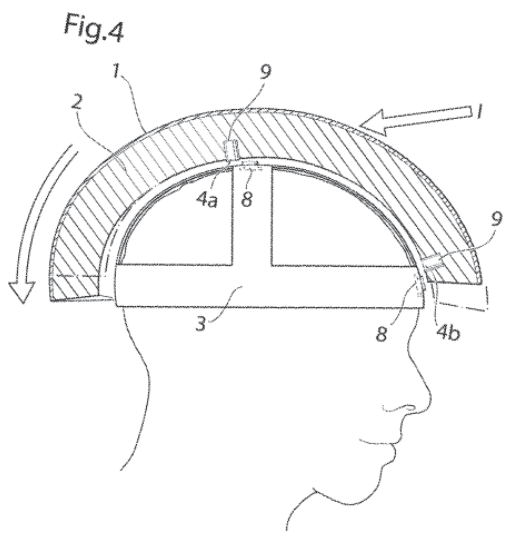
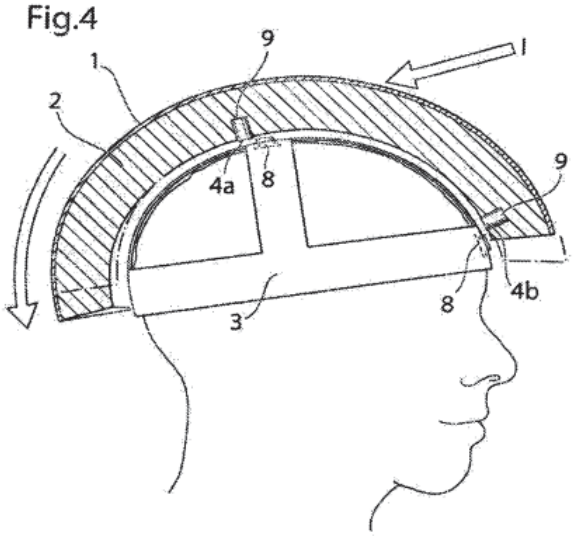
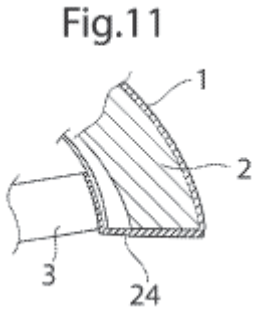
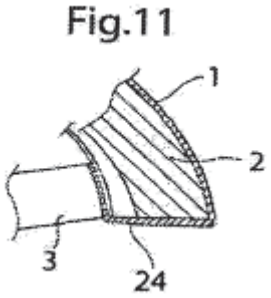
B. Ground 2: Claims 1-4, 6, 8-12, 14, and 16-20 are Obvious over Von Holst Combined with Halldin and Puchalski

1. Support for Halldin in its Provisional Application

167. I have been informed and understand that a published patent application is entitled to use the filing date of a beneficially claimed provisional application as an effective prior art date, so long as the subject matter relied on in the application is described in the provisional application and at least one of the claims in the application is supported by the written description of the provisional application.

168. It is my view that the subject matter relied on in Halldin is described in the Halldin Provisional application. In the below chart, I have summarized where each part of Halldin's disclosure that I rely upon in my analysis finds written description support in the Halldin Provisional. In short, based on my review of the Halldin Provisional, it conveys to a person of ordinary skill in the art that the applicants of Halldin provided written description in the Halldin Provisional of each disclosure I rely upon from Halldin.

Halldin	*Halldin Provisional*
Fig. 2 	Fig. 2 
Fig. 3 	Fig. 3 
Fig. 4	Fig. 4

	
Fig. 11	Fig. 11
	
Title "Helmet with sliding facilitator arranged at energy absorbing layer"	[0001] "The present invention relates generally to a helmet comprising an energy absorbing layer, with or without any outer shell, and a sliding facilitator being provided inside of the energy absorbing layer."
[0001] "The present invention relates generally to a helmet comprising an energy absorbing layer, with or without any outer shell, and a sliding facilitator being provided inside of the energy absorbing layer."	[0001] "The present invention relates generally to a helmet comprising an energy absorbing layer, with or without any outer shell, and a sliding facilitator being provided inside of the energy absorbing layer."
[0005]	[0005]

"The most common type of impact is oblique impact that is a combination of a radial and a tangential force acting at the same time to the head, causing for example concussion of the brain. The oblique impact results in both translational acceleration and rotational acceleration of the brain. Rotational acceleration causes the brain to rotate within the skull creating injuries on bodily elements connecting the brain to the skull and also to the brain itself."	"The most common type of impact is oblique impact that is a combination of a radial and a tangential force acting at the same time to the head. The oblique impact results in both translational acceleration and rotational acceleration of the brain. Rotational acceleration causes the brain to rotate within the skull creating injuries on bodily elements connecting the brain to the skull and also to the brain itself."
[0012] "Preferably an outer shell is provided outside of the energy absorbing layer. A helmet designed accordingly could be manufactured using in-mould technology, although it is possible to use the disclosed idea in helmets of all types, for example helmets of hard shell type such as motorcycle helmets."	[0011] "Preferably an outer shell is provided outside of the energy absorbing layer. A helmet designed accordingly could be manufactured using in-mould technology, although it is possible to use the disclosed idea in helmets of all types."
[0013] "According to yet another embodiment the attachment device is fixated to the energy absorbing layer and/ or the outer shell by means of at least one fixation member, which could be adapted to absorb energy and forces by deforming in an elastic, semi-elastic or plastic way. During an impact, the energy absorbing layer acts as an impact absorber by	[0012] "According to yet another embodiment the attachment device is fixated to the energy absorbing layer and/ or the outer shell by means of at least one fixation member, which could be adapted to absorb energy and forces by deforming in an elastic, semi-elastic or plastic way. During an impact, the energy absorbing layer acts as an impact absorber by compressing the energy absorbing layer and if an outer shell is used, it will spread out the impact energy over the

compressing the energy absorbing layer and if an outer shell is used, it will spread out the impact energy over the shell. The sliding facilitator will allow sliding between the attachment device and the energy absorbing layer allowing for a controlled way to absorb the rotational energy otherwise transmitted to the brain. The rotational energy can be absorbed by friction heat, energy absorbing layer deformation or, deformation or displacement of the at least one fixation member. The absorbed rotational energy will reduce the amount of rotational acceleration affecting the brain, thus reducing the rotation of the brain within the skull."	shell. The sliding facilitator will allow sliding between the attachment device and the energy absorbing layer allowing for a controlled way to absorb the rotational energy otherwise transmitted to the brain. The rotational energy can be absorbed by friction heat, energy absorbing layer deformation or, deformation or displacement of the at least one fixation member. The absorbed rotational energy will reduce the amount of rotational acceleration affecting the brain, thus reducing the rotation of the brain within the skull."
[0041] "During an impact, the energy absorbing layer acts as an impact absorber by compressing the energy absorbing layer and if an outer shell is used, it will spread out the impact energy over the energy absorbing layer. The sliding facilitator will allow sliding between the attachment device and the energy absorbing layer allowing for a controlled way to absorb the rotational energy otherwise transmitted to the brain The rotational energy can be absorbed by friction heat, energy absorbing layer deformation or deformation or displacement of the	[0039] "During an impact, the energy absorbing layer acts as an impact absorber by compressing the energy absorbing layer and if an outer shell is used, it will spread out the impact energy over the shell. The sliding facilitator will allow sliding between the attachment device and the energy absorbing layer allowing for a controlled way to absorb the rotational energy otherwise transmitted to the brain The rotational energy can be absorbed by friction heat, energy absorbing layer deformation or deformation or displacement of the at least one fixation member. The absorbed rotational energy will reduce the amount of rotational acceleration affecting the brain, thus

at least one fixation member. The absorbed rotational energy will reduce the amount of rotational acceleration affecting the brain, thus reducing the rotation of the brain within the skull. The risk of rotational injuries such as subdural haematomas, SDH, blood vessel rupturing, concussions and DAI is thereby reduced."	reducing the rotation of the brain within the skull. The risk of rotational injuries such as subdural haematomas, SH, blood vessel rupturing and DAI is thereby reduced."
[0042] "Fig. 1 shows a helmet according to one embodiment in which the helmet comprises an energy absorbing layer 2. The outer surface 1 of the energy absorbing layer 2 may be provided from the same material as the energy absorbing layer 2 or it is also conceivable that the outer surface 1 could be a rigid shell 1 made from a different material than the energy absorbing layer 2. A sliding facilitator 5 is provided inside of the energy absorbing layer 2 in relation to an attachment device 3 provided for attachment of the helmet to a wearer's head. According to the embodiment shown in fig. 1 the sliding facilitator 5 is fixated to or integrated in the energy absorbing layer 2, however it is equally conceivable that the sliding facilitator 5 is provided on or integrated with the attachment device 3, for the same purpose of providing slidability between the	[0040] "Fig. 1 shows a helmet according to one embodiment in which the helmet comprises an energy absorbing layer 2. The outer surface 1 of the energy absorbing layer 2 may be provided from the same material as the energy absorbing layer 2 or it is also conceivable that the outer surface 1 could be a rigid shell 1 made from a different material than the energy absorbing layer 2. A sliding facilitator 5 is provided inside of the energy absorbing layer 2 in relation to an attachment device 3 provided for attachment of the helmet to a wearer's head. According to the embodiment shown in fig. 1 the sliding facilitator 5 is fixated to or integrated in the energy absorbing layer 2, however it is equally conceivable that the sliding facilitator 5 is provided on or integrated with the attachment device 3, for the same purpose of providing slidability between the energy absorbing layer 2 and the attachment device 3. The helmet of fig. 1 has a plurality of vents 17 allowing airflow through the helmet."

energy absorbing layer 2 and the attachment device 3. The helmet of fig. 1 has a plurality of vents 17 allowing airflow through the helmet."	
[0043] "The attachment device 3 is fixated to the energy absorbing layer 2 and/ or the outer shell 1 by means of four fixation members 4a, 4b, 4c and 4d adapted to absorb energy by deforming in an elastic, semi-elastic or plastic way. Energy could also be absorbed through friction creating heat and/ or deformation of the attachment device, or any other part of the helmet. According to the embodiment shown in fig. 1 the four fixation members 4a, 4b, 4c and 4d are suspension members 4a, 4b, 4c, 4d, having first and second portions 8, 9, wherein the first portions 8 of the suspension members 4a, 4b, 4c, 4d are adapted to be fixated to the attachment device 3, and the second portions 9 of the suspension members 4a, 4b, 4c, 4d are adapted to be fixated to the energy absorbing layer 2."	[0041] "The attachment device 3 is fixated to the energy absorbing layer 2 and/or the outer shell 1 by means of four fixation members 4a, 4b, 4c and 4d adapted to absorb energy by deforming in an elastic, semi-elastic or plastic way. Energy could also be absorbed through friction creating heat and/or deformation of the attachment device, or any other part of the helmet. According to the embodiment shown in fig. 1 the four fixation members. 4a, 4b, 4c and 4d are suspension members 4a, 4b, 4c, 4d, having first and second portions 8, 9, wherein the first portions 8 of the suspension members 4a, 4b, 4c. 4d are adapted to be fixated to the attachment device 3, and the second portions 9 of the suspension members 4B, 4b, 4c, 4d are adapted to be fixated to the energy absorbing layer 2. The sliding facilitator 5 may be a low friction material, which in the embodiment shown is provided on outside of the attachment device 3 facing the energy absorbing layer 2, however, in other embodiments, it is equally conceivable that the sliding facilitator 5 is provided on the inside of the energy absorbing layer 2. The low friction material could be a waxy polymer, such as PTFE, PFA, FEP, PE and UHMWPE, or a powder material which could be infused with a lubricant. This low friction material could be applied to either one, or both of

	the sliding facilitator and the energy absorbing layer, in some embodiments the energy absorbing layer self is adapted to act as sliding facilitator and may comprise a low friction material. The attachment device could be made of an elastic or semi-elastic polymer material, such as PC, ABS, PVC or PTFE, or a natural fiber material such as cotton cloth. Fig. 1 further discloses an adjustment device 6 for adjusting the diameter of the head band for the particular wearer. In other embodiments the head band could be an elastic head band in which case the adjustment device 6 could be excluded."
[0044] "The sliding facilitator 5 may be a low friction material, which in the embodiment shown is provided on outside of the attachment device 3 facing the energy absorbing layer 2, however, in other embodiments, it is equally conceivable that the sliding facilitator 5 is provided on the inside of the energy absorbing layer 2. The low friction material could be a waxy polymer, such as PTFE, PFA, FEP, PE and UHMW PE, or a powder material which could be infused with a lubricant. This low friction material could be applied to either one, or both of the sliding facilitator and the energy absorbing layer, in some embodiments the energy absorbing layer itself is adapted to act as sliding facilitator and may comprise a low friction material."	[0041] "The sliding facilitator 5 may be a low friction material, which in the embodiment shown is provided on outside of the attachment device 3 facing the energy absorbing layer 2, however, in other embodiments, it is equally conceivable that the sliding facilitator 5 is provided on the inside of the energy absorbing layer 2. The low friction material could be a waxy polymer, such as PTFE, PFA, FEP, PE and UHMWPE, or a powder material which could be infused with a lubricant. This low friction material could be applied to either one, or both of the sliding facilitator and the energy absorbing layer, in some embodiments the energy absorbing layer itself is adapted to act as sliding facilitator and may comprise a low friction material."

[0046] "Fig. 2 shows an embodiment of a helmet similar to the helmet in fig.1, when placed on a wearers head. However, in fig. 2 the attachment device 3 is fixated to the energy absorbing layer by means of only two fixation members 4a, b, adapted to absorb energy and forces elastically, semi-elastically or plastically. The embodiment of fig. 2 comprises a hard outer shell 1 made from a different material than the energy absorbing layer 2."	[0042] "Fig. 2 shows an embodiment of a helmet similar to the helmet in fig.1, when placed on a wearers head. However, in fig. 2 the attachment device 3 is fixated to the energy absorbing layer by means of only two fixation members 4a, b, adapted to absorb energy and forces elastically, semi-elastically or plastically. The embodiment of fig. 2 comprises a hard outer shell 1 made from a different material than the energy absorbing layer 2."
[0047] "Fig. 3 shows the helmet according to the embodiment of fig. 2 when receiving a frontal oblique impact I creating a rotational force to the helmet causing the energy absorbing layer 2 to slide in relation to the attachment device 3. The attachment device 3 is fixated to the energy absorbing layer 2 by means of the fixation members 4a, 4b. The fixation absorbs the rotational forces by deforming elastically or semi-elastically."	[0043] "Fig. 3 shows the helmet according to the embodiment of fig. 2 when receiving a frontal oblique impact I creating a rotational force to the helmet causing the energy absorbing layer 2 to slide in relation to the attachment device 3. The attachment device 3 is fixated to the energy absorbing layer 2 by means of the fixation members 4a, 4b. The fixation absorbs the rotational forces by deforming elastically or semi-elastically."
[0048] "Fig. 4 shows the helmet according to the embodiment of fig. 2 when receiving a frontal oblique impact I creating a rotational force to the helmet causing the energy absorbing layer 2 to slide in relation to the	[0044] "Fig. 4 shows the helmet according to the embodiment of fig. 2 when receiving a frontal oblique impact I creating a rotational force to the helmet causing the energy absorbing layer 2 to slide in relation to the attachment device 3. The attachment device 3 is fixated to the energy absorbing

attachment device 3. The attachment device 3 is fixated to the energy absorbing layer by means of rupturing fixation members 4a, 4b which absorbs the rotational energy by deforming plastically and thus needs to be replaced after impact. A combination of the embodiments of fig. 3 and fig. 4 is highly conceivable, i.e. a portion of the fixation members ruptures, absorbing energy plastically, while another portion of the fixation members deforms and absorbs forces elastically. In combinational embodiments it is conceivable that only the plastically deforming portion needs to be replaced after impact."	layer by means of rupturing fixation members 4a, 4b which absorbs the rotational energy by deforming plastically and thus needs to be replaced after impact. A combination of the embodiments of fig. 3 and fig. 4 is highly conceivable, i.e. a portion of the fixation members ruptures, absorbing energy plastically, while another portion of the fixation members deforms and absorbs forces elastically. In combinational embodiments it is conceivable that only the plastically deforming portion needs to be replaced after impact."
[0050] "Fig. 5 further shows four fixation members 4a, 4b, 4c, 4d, fixated to the attachment device 3. In other embodiments the attachment device 3 could be only a head band 3a, or en entire cap adapted to entirely cover the upper portion of the wearer's head or any other design functioning as an attachment device for mounting on a wearer's head."	[0046] "Fig. 5 further shows four fixation members 4a, 4b, 4c, 4d, fixated to the attachment device 3. In other embodiments the attachment device 3 could be only a head band 3a, or en entire cap adapted to entirely cover the upper portion of the wearer's head or any other design functioning as an attachment device for mounting on a wearer's head."
[0052] "Fig. 6 shows an alternative embodiment of a fixation member 4 in which the first portion 8 of the fixation member 4 is fixated to the attachment device 3, and the	[0048] "Fig. 6 shows an alternative embodiment of a fixation member 4 in which the first portion 8 of the fixation member 4 is fixated to the attachment device 3, and the second portion 9 of the fixation device 4 is

second portion 9 of the fixation device 4 is fixated to the energy absorbing layer 2 by means of an adhesive. The fixation member 4 is adapted to absorb impact energy and forces by deforming in an elastic, semi-elastic or plastic way."	fixated to the energy absorbing layer 2 by means of an adhesive. The fixation member 4 is adapted to absorb impact energy and forces by deforming in an elastic, semi-elastic or plastic way."
[0055] "Fig. 9 shows a fixation member 4 in a sectional view and an A-A view. The attachment device 3 is according to this embodiment attached to the energy absorbing layer 2 by means of the fixation member 4 having a second portion 9 placed in a female part 12 adapted for elastic, semi-elastic or plastic deformation, and a first part 8 connected to the attachment device 3. The female part 12 comprises flanges 13 adapted to flex or deform elastically, semi-elastically or plastically when placed under a large enough strain by the fixation member 4 so that the second portion 9 may leave the female part 12."	[0051] "Fig. 9 shows a fixation member 4 in a sectional view and an A-A view. The attachment device 3 is according to this embodiment attached to the energy absorbing layer 2 by means of the fixation member 4 having a second portion 9 placed in a female part 12 adapted for elastic, semi-elastic or plastic deformation, and a first part 8 connected to the attachment device 3. The female part 12 comprises flanges 13 adapted to flex or deform elastically, semi-elastically or plastically when placed under a large enough strain by the fixation member 4 so that the second portion 9 may leave the female part 12."
[0057] "Fig. 11 shows an embodiment in which the attachment device 3 is fixated to the energy absorbing layer 2 at the periphery thereof by means of a membrane or sealing foam 24, which could be elastic or adapted for plastic deformation."	[0053] "Fig. 11 shows an embodiment in which the attachment device 3 is fixated to the energy absorbing layer 2 at the periphery thereof by means of a membrane or sealing foam 24, which could be elastic or adapted for plastic deformation."

[0059] "Fig. 13 shows an embodiment in which the fixating member is an interconnecting sandwich layer 27, such as a sandwich cloth, which could comprise elastically, semi-elastically or plastically deformable fibers connecting the attachment device 3 to the energy absorbing layer 2 and being adapted to shear when shearing forces are applied and thus absorb rotational energy or forces."	[0055] "Fig. 13 shows an embodiment in which the fixating member is an interconnecting sandwich layer 27, such as a sandwich cloth, which could comprise elastically, semi-elastically or plastically deformable fibers connecting the attachment device 3 to the energy absorbing layer 2 and being adapted to shear when shearing forces are applied and thus absorb rotational energy or forces."
[0062] "In the embodiments disclosed herein the distance between the energy absorbing layer and the attachment device could vary from being practically nothing to being a substantial distance without parting from the concept of the invention."	[0058] "In the embodiments disclosed herein the distance between the energy absorbing layer and the attachment device could vary from being practically nothing to being a substantial distance without parting from the concept of the invention."
[0064] "In embodiments comprising several fixation members it is further more conceivable that one of the fixation members is a master fixation member adapted to deform plastically when placed under a large enough strain, whereas the additional fixation members are adapted for purely elastic deformation."	[0060] "In embodiments comprising several fixation members it is further more conceivable that one of the fixation members is a master fixation member adapted to deform plastically when placed under a large enough strain, whereas the additional fixation members are adapted for purely elastic deformation."
[0069] "Please note that any embodiment or part of embodiment as well as any method or part of method could be combined in any way. All	[0064] "Please note that any embodiment or part of embodiment as well as any method or part of method could be combined in any way. All examples herein should be seen as part

examples herein should be seen as part of the general description and therefore possible to combine in any way in general terms."	of the general description and therefore possible to combine in any way in general terms."

169. Further, in my opinion, the Halldin Provisional provides written-description support for at least claim 7 of Halldin. In the below chart, I have summarized where each part of Halldin claim 7 finds written description support in the Halldin provisional. In short, based on my review of the Halldin Provisional, it conveys to a person of ordinary skill in the art that the applicants of Halldin had provided written description in that Halldin Provisional of claim 7 of Halldin, including through claim 9 of the Halldin Provision, which is identical to claim 7 of Halldin.

Halldin	*Halldin Provisional*
7. A method of manufacturing a helmet comprising a sliding facilitator, the method comprising the steps of:	Claim 9 "A method of manufacturing a helmet comprising a sliding facilitator, the method comprising the steps of:" [0008] [0011] [0014] "A method of manufacturing a helmet comprising a sliding facilitator is further provided."

	[0041] "The sliding facilitator 5 . . . ."
providing an energy absorbing layer in a mould, and	Claim 9 "providing an energy absorbing layer in a mould, and" [0008] "Modern bicycle helmets are usually of the type in-mould shell . . . ." [0011] "Preferably an outer shell is provided outside of the energy absorbing layer. A helmet designed accordingly could be manufactured using in-mould technology[] . . . ." [0014] "A method of of manufacturing a helmet comprising a sliding facilitator is further provided. The method comprising the steps of: providing a mould, providing an energy absorbing layer in the mould[] . . . ." [0041]
providing a sliding facilitator in relation to the energy absorbing layer.	Claim 9 "providing a sliding facilitator in relation to

	the energy absorbing layer." [0008] [0011] [0014] "A method of manufacturing a helmet comprising a sliding facilitator is further provided. The method comprising the steps of: providing a mould, providing an energy absorbing layer in the mould, and providing a sliding facilitator contacting the energy absorbing layer." [0041] "The sliding facilitator 5 . . . ."

2. Claim 1

a) 1[preamble]: "A helmet comprising:"

170. Von Holst discloses "a helmet." Von Holst discloses multiple embodiments of a "protective helmet," including a helmet in Figures 1-2, and then in Figure 3 a series of "variants" of the helmet from Figure 1.

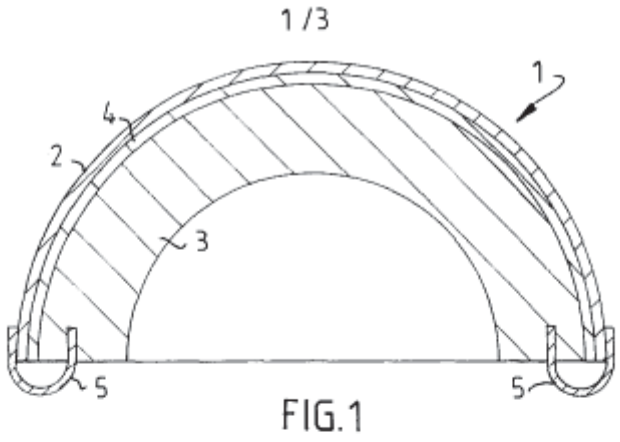


FIG.1

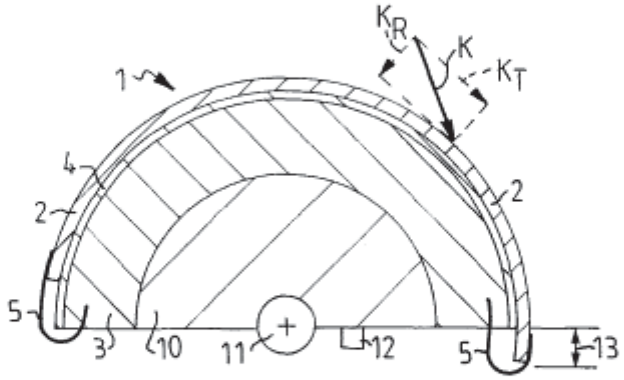


FIG.2

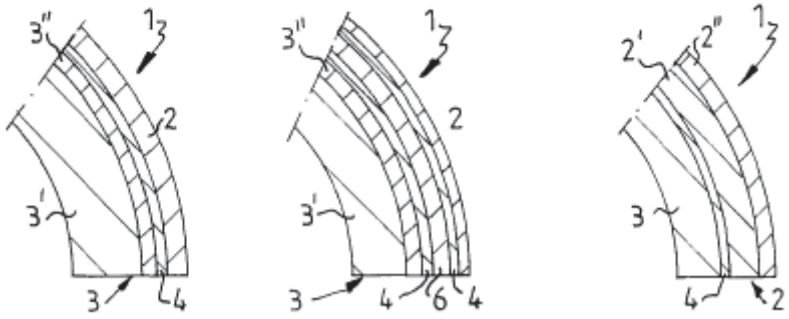


FIG.3a FIG.3b FIG.3c

Ex.1005[VonHolst], 4:10-14, 5:36-6:2, Figs. 1-3.

b) 1[a]: "an outer shell layer;"

171. Von Holst discloses "an outer shell layer." Von Holst discloses a helmet "constructed from an **outer shell 2**…." Ex.1005[VonHolst], 4:10-12, Figs. 1-3.

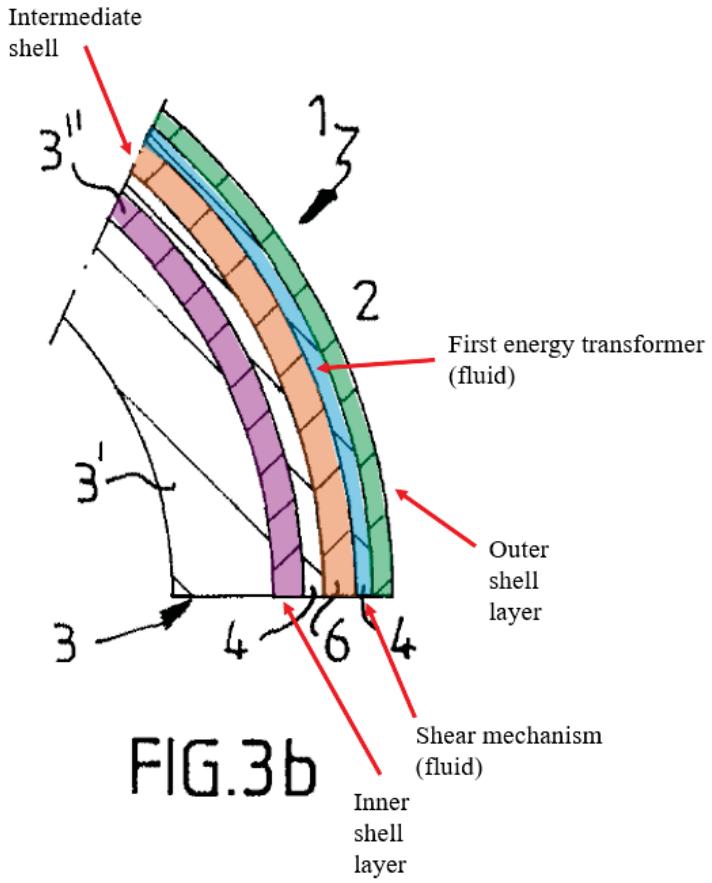


FIG.3b

Ex.1005[VonHolst], FIG. 3b

c) 1[b]: "an inner shell layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

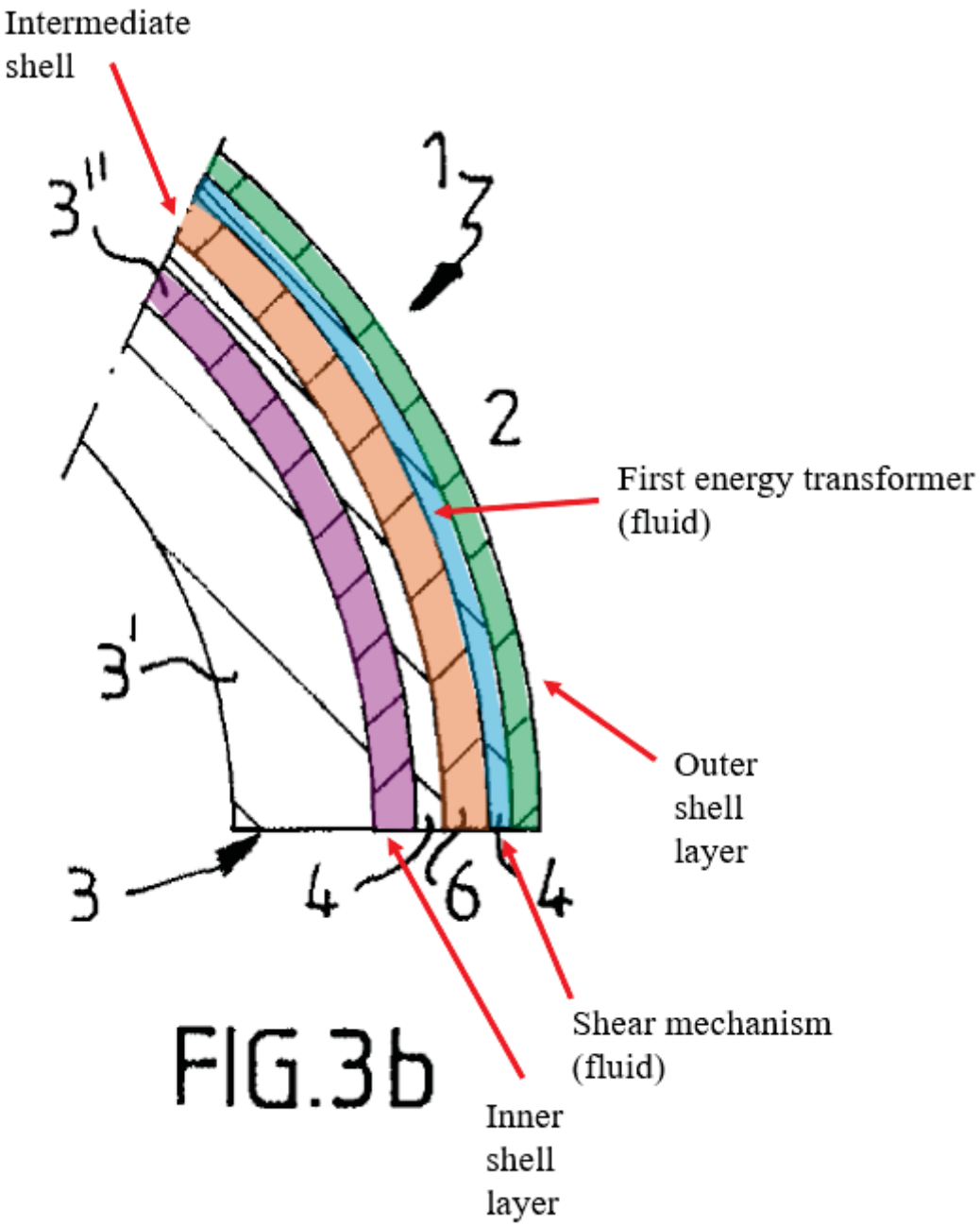
172. In my opinion, Von Holst combined with Halldin discloses "an inner shell layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material." Von Holst describes an "outer sliding layer 4" which is the "first energy transformer."

173. Von Holst discloses "an inner shell layer." Von Holst discloses a helmet with an "inner shell 3 [] constructed from a harder, relatively thin outer layer 3" [(i.e., the inner shell layer)] and a softer, relatively thick inner layer 3'. In Fig. 3b, the inner shell 3 is constructed in the same manner as in Fig. 3a." Ex.1005[VonHolst], 5:39-6:4. As shown below in Figure 3b of Von Holst, the helmet has an **outer layer 3"** of inner shell 3 ("inner shell layer"), **outer shell 2** ("outer shell layer") and inner and **outer "sliding layers 4**, between which there is an intermediate shell 6." Ex.1005[VonHolst], 6:4-6. The sliding layers can be made of different materials including oil or air. *Id.*, 4:33-34.

174. Von Holst discloses components connecting its **outer layer 3"** of inner shell 3 and **outer shell 2**—e.g., **sliding layers 4**, in the combination with Halldin described below, **fixation members**—that constitute a "shear mechanism" because

they shear and allow relative sliding and energy transformation. Ex.1005[VonHolst], 6:4-6, FIG. 3; *id.* claims 1, 4; Ex.1006[Halldin], [0041], [0043].

175. Von Holst's "shear mechanism" includes an **outer sliding layer**, which is a first transformer that resides between and connects the **inner shell** and **outer shell** of Von Holst. This outer sliding layer 4 of (e.g., oil or air) is an "energy transformer" because it "facilitates mutual displacement" between the inner and outer shell "by sliding" and contains elements that transform energy by doing so. Ex.1005[VonHolst], Abstract, 4:15-17, 5:31-34, 6:35-7:10, 8:12-14, Figs. 4-6, cls. 1, 4. Von Holst's outer sliding layer of oil or air includes a first energy transformer having an absorptive/dissipative material because it transforms energy by absorbing and dissipating it via sliding and through the creation of heat from friction when the outer shell layer is allowed to slide relative to its inner shell layer. Ex.1005[VonHolst], Abstract, 4:15-17, 5:31-34, 6:35-7:10, Figs. 4-6, cls. 1, 4. Sliding layer 4 of oil or air further absorbs energy as friction between the layers, converting impact energy to heat. Ex.1005[VonHolst], 4:32-34, 6:8-10, 7:38-8:2 (describing friction)); *see also id.*, 5:21-34 (25% reduction in force with oil film). Oil and air are both fluids, which the '635 patent recognizes as absorptive/dissipative materials. Ex.1001[USP635], 6:43-45.

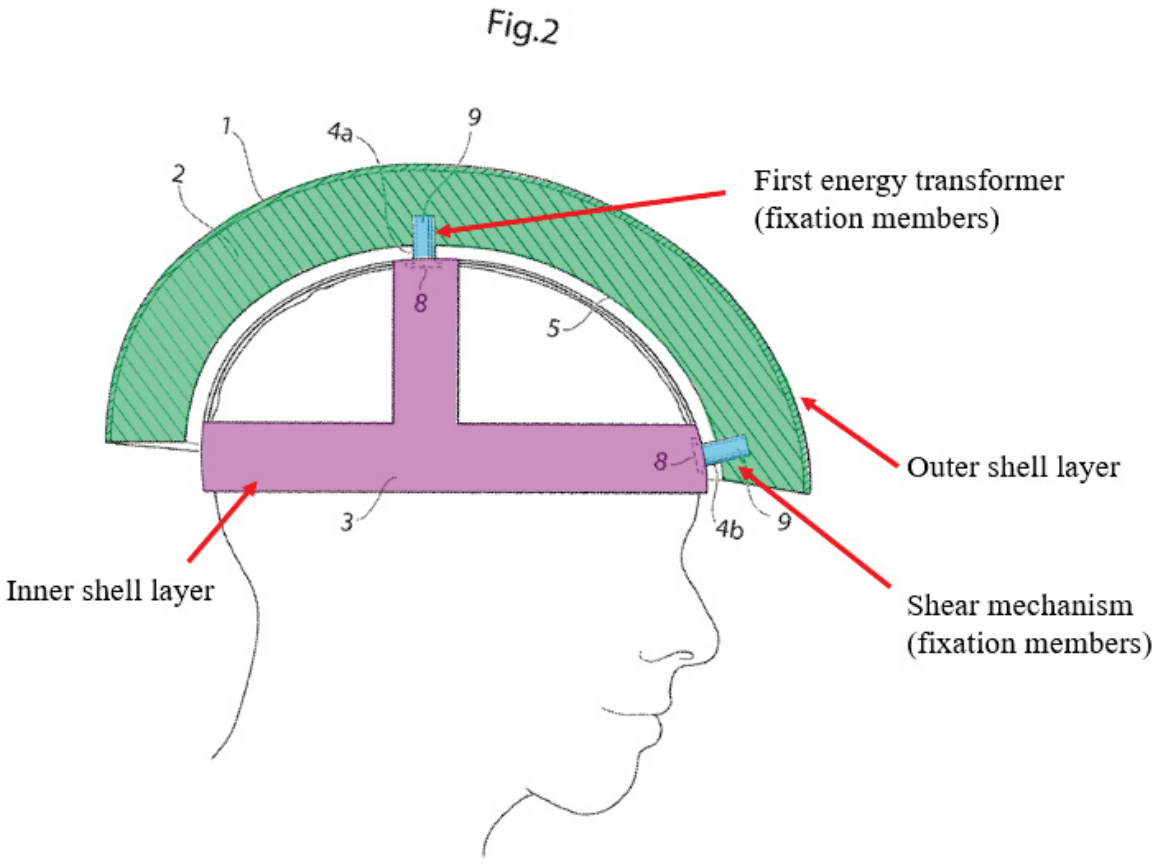


Ex.1005[VonHolst], FIG. 3; see also *id.*, cls. 1, 4.

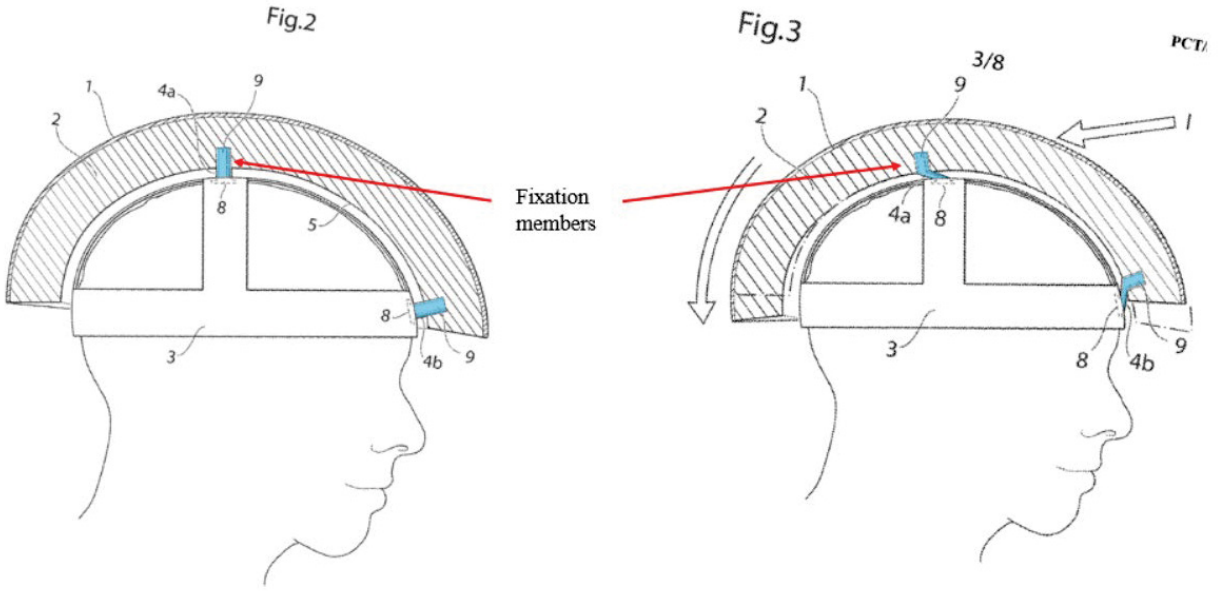
176. Halldin teaches components, such as fixation members, that shear and allow relative sliding and energy transformation, Ex.1006[Halldin], [0041], [0043],

which a POSA would have been motivated to include between Von Holst's outer and inner shells with a reasonable expectation of success. Halldin teaches a helmet with **fixation members** that connect an outer and inner layer and allow or support relative sliding between the outer and inner layer, as I show below in annotated Figure 2 of Halldin. Ex.1006[Halldin], [0013], [0047-48]; *see also id.*, Fig. 3. Halldin describes several types of fixation members, such as members 4a-4d, that "absorb energy by deforming in an elastic, semi-elastic or plastic way." Ex.1006[Halldin], [0043], Figs. 2-3. Halldin's "**energy absorbing layer 2**" (which contains an outer shell layer) can slide with respect to "**attachment device 3**" (an inner shell layer) and the **fixation members 4a and 4b** are located between these two shells/layers. *Id.*, [0047], Figure 2; *see also* Figure 3. Halldin teaches that "[t]he fixation [from the fixation members] absorbs the rotational forces by deforming elastically or semi-elastically". *Id.*, [0047]. Halldin's Figures 2 and 3 (annotated below) show that the fixation members 4a and 4b are connected to an "energy absorbing layer 2" (*i.e.*, the outer shell layer) at "portion 9" and to an "attachment device 3" (*i.e.*, the inner shell layer) at "portion 8." *Id.*, Figs. 2-3. To a person of ordinary skill in the art, Halldin discloses that its fixation members (*i.e.*, fixation members 4a and 4b) allow relative sliding between the inner and outer shell layers

by deforming and thereby allowing the outer shell layer to slide relative to the inner shell layer.



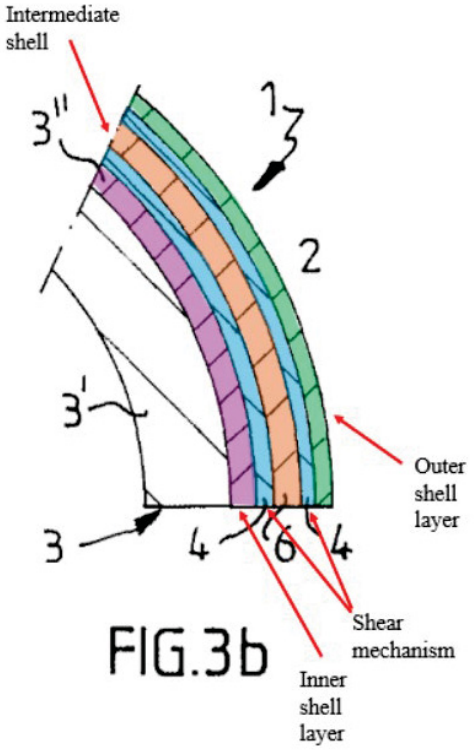
Ex.1006[Halldin], Fig. 2; *see also id.*, Fig. 3.



Ex.1006[Halldin], Figs. 2, 3.

177. In my opinion, Von Holst combined with Halldin discloses 1[b] in at least as much detail as the '635 Patent, if not more. For example, to a POSA, the combination of Von Holst and Halldin discloses at least a shear mechanism that includes a first energy transformer. This is illustrated by Figure 3b of Von Holst in combination with Figure 2 of Halldin. The shear mechanism is located between and connects Von Holst's **outer layer 3"** of inner shell 3 (inner shell layer) and **outer shell 2** (outer shell layer). It includes Von Holst's inner and outer **sliding layers 4**, between which lies an intermediate shell 6. Additionally, the mechanism incorporates Halldin's **fixation members**. The inner and outer oil or air sliding layers, as well as the fixation members incorporated therein, are a shear mechanism that connects Von Holst's inner and outer shells. As I discussed in Ground 1 with

respect to Weber, connection per the '635 Patent may be indirect. *See* my discussion at Section X.A.2.c).



Ex.1005[VonHolst], FIG. 3; *see also id.*, cls. 1, 4.

178. In addition to Von Holst's shear mechanism to facilitate mutual displacement between the inner and outer shells by sliding. Ex.1005 [Von Holst], 8:12-14. The outer sliding layer, composed of "oil, Teflon, microspheres, air, rubber etc." acts as a first energy transformer made of absorptive/dissipative material. Ex.1005[VonHolst], 4:32-34, 6:8-10. It transforms impact energy by absorbing/dissipating it through sliding motion and by generating heat from friction as the outer shell layer slides relative to the inner shell layer. Ex.1005 [Von Holst],

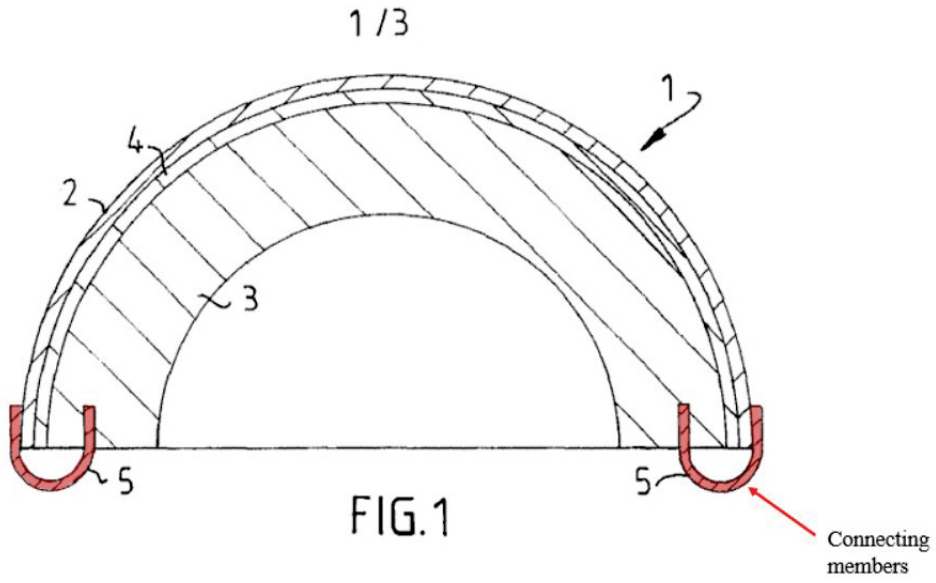
Abstract; 4:15-17; 5:31-34; 6:35-7:10; Figs. 4-6; cls. 1, 4. Friction converts, or transforms some energy imparted onto the layers into heat. This is consistent with the '635 Patent's recitation of its energy and impact transformer layers. Ex.1001[USP635], 9:27-30 ("By allowing sliding movements that convert potential head rotational forces into heat or transformation energy, shear forces can be significantly reduced."). Both oil and air are fluids, which the '635 Patent identifies as absorptive/dissipative materials. Ex.1001[USP635], 6:43-45. In these ways, Von Holst's outer sliding layer 4 (the "first energy transformer") absorbs energy from mechanical forces imparted onto the outer shell 2. Described above, Halldin's fixation members, when incorporated into Von Holst's sliding layers, also function as part of a shear mechanism. Halldin, which shares an inventor with Von Holst, teaches that these fixation members transform energy by deforming and shearing, while also permitting relative sliding between the inner and outer layers. Ex.1006 [Halldin], [0013], [0047]-[0048]. When integrated into Von Holst's outer sliding layer 4, the fixation members serve as a first energy transformer composed of absorptive and dissipative material. Halldin specifically discloses fixation members 4a–4d that "absorb energy," specifically by "deforming in an elastic, semi-elastic or plastic way." Ex.1006 [Halldin], [0043], Figs. 2-3, [0047]. And as I have discussed above, these members further absorb/dissipate energy by their mechanical

deformation upon impact and enabling relative sliding. Ex.1006[Halldin], [0013], [0043], [0047-48]. These fixation members thus further supplement the energy absorption achieved by Von Holst's sliding layers 4.

179. As I discussed above, the shear mechanism does not, in my opinion, include a "middle layer." See my discussion in Section X.A.2.c). But alternatively, if Patent Owner argues otherwise and a middle layer is part of the shear mechanism, as Figure 3b shows, Von Holst discloses intermediate shell 6. In that case, the shear mechanism would include Von Holst's "intermediate shell 6" in addition to Von Holst's "sliding layer 4" (when made from oil or air), and Halldin's fixation members (which would be placed within "sliding layer 4"). Outer "sliding layer 4" is between Von Holst's "intermediate shell 6" and its "outer shell 2" (see Figure 3b of Von Holst shown above). This configuration would allow the outer shell layer to "shear" relative to the inner shell layer (*i.e.*, Von Holst's **outer layer 3"** of inner shell 3).

180. In my opinion, a POSA would have been motivated to modify Von Holst to incorporate Halldin's fixation members, such as those placed in Von Holst's sliding layer 4. Von Holst and Halldin are analogous to the challenged claims because both relate to helmet safety design and address the same problem—reducing rotational impact—through the same solution of improved helmet sliding

mechanisms. Notably, the two references also share a common inventor. Von Holst discloses "connecting member 5" made from deformable strips of plastic. Ex.1005[VonHolst], 4:38-5:2; *id.*, 4:17-21; *id.*, 5:36-39 (Figure 3 is described as a "variant" of the layers of "protective helmet 1" (*i.e.*, Figure 1) and includes connecting members). As I show in annotated Figure 1 below, Von Holst describes "**connecting member 5**" connecting "outer shell 2" and "inner layer 3'" (as well as the layers in between). The connecting members are made from deformable strips of plastic and connect outer shell 2 and **outer layer 3"** of inner shell 3 and also "absorb energy." Ex.1005[VonHolst], 4:17-21.



Ex.1005[VonHolst], Fig. 1.

181. While Von Holst describes connecting layers using transformer layers and "**connecting member 5**", Halldin, filed later, discloses additional techniques for

connecting layers while preserving sliding functionality. These include internal connections, such as fixation members 4a-4d. Ex.1006 [Halldin], [0057], Fig. 11, [0048], [0064], [0069]. In my opinion, a POSA would have been motivated to use Halldin's internal fixation members to replace or supplement Von Holst's connecting member 5. Indeed, Halldin itself teaches that fixation at the periphery and fixation at internal locations are alternatives and could be used either in place of one another or together in one embodiment. See Ex.1006[Halldin], [0057], Fig. 11, [0064] (discussing combination of "master fixation member" and "additional fixation members"). Therefore, peripheral and internal fixation were known, available alternatives that could be used independently or in combination. Also, Halldin teaches that incorporating internal fixation members would increase the connection points throughout the helmet and enhance energy absorption. Ex.1006 [Halldin], [0043]. In my opinion, combining these elements would have been an obvious and routine design choice for a POSA. The integration of known components using established methods would yield predictable results. Von Holst's helmet is well-suited for improvement through the addition of a layer of energy-absorbing internal fixation members. Applying Halldin's known technique of using fixation members to connect layers and absorb energy would enhance Von Holst's helmet in a similar manner.

182. In my opinion, a POSA would have had a reasonable expectation of successfully modifying Von Holst's design to incorporate Halldin's fixation members. Halldin's helmet design is readily applicable to Von Holst's, as both address similar structural and functional goals. Like Von Holst's sliding layers, Halldin describes a "sliding facilitator 5 [Fig. 2] [that] may be a low friction material," which "is provided on outside of the attachment device 3 facing the energy absorbing layer 2" or, alternatively, "on the inside of the energy absorbing layer 2." Ex.1006[Halldin], [0044], Fig. 2. Halldin further recognizes that its fixation members are not exclusive to the specific attachment device embodiments in its specification, and would be readily adaptable to other designs, such as Von Holst's helmets as a matter of routine implementation within the skill of a POSA. A POSA would have readily adapted them to other helmet designs, such as Von Holst's, as a matter of routine design choice. Halldin explicitly states that "the attachment device 3 could be … any other design functioning as an attachment device for mounting on a wearer's head." Ex.1006 [Halldin], [0050]. For instance, Halldin teaches that fixation members can be attached to the outer energy-absorbing layer using an adhesive. Ex.1006 [Halldin], [0052]. This is not the only way in which such fixation members could be fixated between shell layers; for example, the members could be fixated via interlocking pieces or snap fixation. Halldin discusses, for example, that

this connecting may be "by means of the fixation member 4 having a second portion 9 placed in a female part 12 adapted for elastic, semi-elastic or plastic deformation, and a first part 8 connected to the attachment device 3." Ex.1006[Halldin], [0055]. Furthermore, it was well understood in the art to use or include multiple mechanical connection points between two sliding layers. *See, e.g.*, Ex.1004[Weber]; Ex.1007[Kleiven]; Ex.1010[Ferrara-2006]; Ex.1018[Ferrara-2007]. Based at least on these disclosures, a POSA would have reasonably expected success in implementing Halldin's fixation members to connect Von Holst's intermediate and outer shell layers.

d) 1[c]: "the inner shell layer configured to conform to a human head"

183. In my opinion, Von Holst combined with Halldin discloses "the inner shell layer configured to conform to a human head." Von Holst teaches that "inner shell (3) is intended for contact with the head of the wearer," Ex.1005[VonHolst], 9:13-15, and includes the "harder, relatively thin outer layer 3"" of the inner shell layer and a soft inner layer 3'. Ex.1005[VonHolst], 5:39-6:1; 4:26-29. Thus, both outer layer 3" and soft layer 3' of inner shell 3 are designed to conform to a human head. *See* Figs. 1-3, Ex.1005[VonHolst], 6:18-28.

e) 1[d]: "a chin strap attached to the inner shell layer to maintain the position of the inner shell layer on the human

head during rotational force impact while the outer shell layer is allowed to slide."

184. Von Holst combined with Puchalski teaches "a chin strap attached to the inner shell layer to maintain the position of the inner shell layer on the human head during rotational force impact while the outer shell layer is allowed to slide." Puchalski teaches a chin-strap for a helmet and explains that "[a]lthough not essential, most preferably, the helmet chin straps 16 are secured to the peripheral edge of the inner panel 126, along each of its sides." Ex.1011[Puchalski], 12:1-3; Figs. 9-10, *see* my discussion above in Section X.A.2.e), which I incorporate here. A person of ordinary skill in the art would have been motivated to incorporate Puchalski's chin-strap into Von Holst's helmet, including by placing it in the same location that Puchalski teaches (*i.e.*, attached to the inner shell). *See* my discussion above in Section X.A.2.e). It would have been obvious to attach Puchalski's chin-strap to the periphery of Von Holst's inner shell (*i.e.*, an "inner shell layer"). When the chin-strap is attached to this lining layer in Von Holst, it will further improve the fit of the helmet and keep it secured on a human head.

185. In my opinion, a POSA would have been motivated to combine, and have a reasonable expectation of success in combining, Von Holst and Puchalski. It is my opinion that Von Holst and Puchalski are analogous art because they deal with the same problems in helmet design—reducing rotational impact—and goal of

improving helmet design by using multiple sliding shells/layers (*i.e.*, an outer shell layer that slides relative to an inner shell layer).

186. In my opinion, to a POSA reading Puchalski the chin-strap is most preferably placed on an inner shell layer of a helmet where an outer shell layer slides relative to that inner shell layer. This configuration maintains the position of the inner shell layer relative to the wearer's head. In my opinion, it would have been an obvious design choice to place a chin-strap on the inner shell layer that, along with the lining layer, conforms to the wearer's head because this design would have ensured that the helmet stays attached to the wearer's head (by confirming better to it) and allowing the outer shell layer to slide relative to the inner shell layer upon rotational impact on the helmet. *See* my discussion above in Section X.A.2.e), which I incorporate here.

187. As I already discussed above in Section X.A.2.e), there are only a finite number of locations for a chin-strap on a helmet. For example, there are only three

possible layers/liners to attach a chin-strap to: the inner, intermediate, or outer.[11] A POSA would have been motivated to try each of these limited options for the same reasons that I discuss above in Section X.A.2.e). A POSA would also have had a reasonable expectation of success in using Von Holst's helmet and modifying it by simply adding Puchalski's chin-strap attached to the inner layer. As I discussed above, Puchalski teaches placing a chin-strap (including a two-piece design, *see* Figures 9 and 10 of Ex.1011[Puchalski] and my discussion in Section X.A.2.e)) along an inner layer of a helmet, and shows that a POSA would be successful in doing so. In my opinion, it is just a matter of routine experimentation, and would have been conventional, to configure Puchalski's chin-strap to attach within/on the inner shell layer of Von Holst's helmet. *See* my discussion in Section X.A.2.e).

[11] I note that to the extent the sliding layers of Von Holst are considered possible attachment locations (which in my opinion they are not), a POSA would not have attached a chin-strap to sliding layers because this would interfere with the functionality of the sliding layers (*e.g.*, providing a dampening effect) and would also not provide for a secure attachment due to the softer (or even liquid/gas) materials used for the sliding layers.

188. Therefore, in my opinion and for all the reasons discussed above, claim 1 is obvious over Von Holst combined with Halldin and Puchalski.

3. Claim 2

a) "The helmet of claim 1, wherein the shear mechanism is a shear layer."

189. Von Holst combined with Halldin and Puchalski renders claim 1 obvious. *See* my discussion in Section X.B.2, which I incorporate here. Von Holst combined with Halldin discloses "wherein the shear mechanism is a shear layer." For example, Halldin's layer of fixation members with Von Holst's outer sliding layer 4 in the embodiment of Figure 3b teaches a shear mechanism that is a shear layer. Section X.B.2.c).

190. Therefore, in my opinion, claim 2 is obvious over Von Holst combined with Halldin and Puchalski.

4. Claim 3

a) "The helmet of claim 2, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer."

191. Von Holst combined with Halldin and Puchalski renders claim 2 obvious. *See* my discussion in Section X.B.3, which I incorporate here. Von Holst

combined with Halldin teaches "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer."

192. As I discussed above, Von Holst combined with Halldin describes a shear layer that consists of a sliding layer of oil or air combined with fixation members. Section X.B.3. This shear layer is connected to the outer shell layer through a first energy transforming component, which includes the outer layer of fluids or fixation members. See Sections X.B.2-X.B.3; Ex.1005 [Von Holst],[VonHolst], 6:2-6, Fig. 3b; *see also id*., cls. 1 and 4; Ex.1006 [Halldin], [0013], [0047], [0048]. The outer sliding layer of oil or air and the fixation members are absorptive/dissipative materials that enable the claimed sliding motion, connect the outer and inner shells, and absorb energy imparted on the outer shell layer. Section X.B.2.c). , Von Holst discloses a "connecting member 5" made of deformable plastic strips that connect the outer shell (2) and inner layer (3') of a protective helmet, as well as the intermediate layers. These connecting members are designed to absorb energy. Figure 3 is described as a variant of Figure 1, which also includes these connecting members. Ex.1005[VonHolst], 4:38-5:2,; *id.*, 4:17-21; *id.*,

5:36-39. Further, Von Holst claim 4 recites "[p]rotective helmet according to any one of Claims 1-3"—claim 1 of which describes the "connecting member"—has "at least two sliding layers (4), an intermediate shell (6) being present between each two of these." Ex.1005[VonHolst], cl. 4. Halldin also teaches a helmet with fixation members that connect an outer and inner shell layers, allowing or supporting relative sliding between them, as discussed in detail in Section X.B.2.c).

193. In my opinion, claim 3 is obvious over Von Holst combined with Halldin and Puchalski.

5. Claim 4

a) "The helmet of claim 3, wherein the inner shell layer is connected to the shear layer, the inner shell layer configured to conform to a human head, the inner shell layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer."

194. Von Holst combined with Halldin and Puchalski renders claim 3 obvious. *See* my discussion in X.B.4, which I incorporate here. Von Holst combined with Halldin teaches "the inner shell layer is connected to the shear layer, the inner shell layer configured to conform to a human head, the inner shell layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb

energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer."

195. Von Holst's inner shell layer, which is shaped to conform to the human head, is connected to both the shear layer and the outer shell layer. Section X.B.2.c). This connection is made through the inner sliding layer 4 and Halldin's fixation members, which together function as a second energy transformer. Ex.1005[VonHolst], 5:38-6:6, Fig. 3b; *see also* X.B.2.c) (noting that the '635 Patent allows for indirect connections). The second energy transformer includes absorptive/dissipative materials found in the inner sliding layer 4, such as oil or air, as well as the fixation members. This structure is operable to absorb energy transmitted through the outer shell layer and the second energy transformer into the shear layer. Section X.B.2; Ex.1005[VonHolst], 4:10-21, 4:32-36, 5:21-34, 6:2-6, Figs. 1-3. At least some of the force applied to the outer shell layer would pass through the outer sliding layer 4 and be absorbed by the second energy transformer (inner sliding layer 4 and fixation members), functioning similarly to the first energy transformer. Ex.1005[VonHolst], 4:32–36, 5:21–34.

196. In my opinion, claim 4 is obvious over Von Holst combined with Halldin and Puchalski.

6. Claim 6

a) "The helmet of claim 1, wherein the first absorptive/dissipative material comprises a fluid."

197. Von Holst combined with Halldin and Puchalski renders claim 1 obvious. Section X.B.2. Von Holst discloses "the first absorptive/dissipative material comprises a fluid." As discussed in Sections X.B.2.c) and X.B.3, Von Holst's sliding layers 4 can comprise "oil" or "air" which are fluids. Ex.1005[VonHolst], 4:32-34. Holst discloses a first energy transformer and a second energy transformer in the form of an outer sliding layer 4 and an inner sliding layer 4, respectively, both of which are made of absorptive/dissipative material. Von Holst also discloses "the first absorptive/dissipative material" and "the second absorptive/dissipative material" are different. For example, Von Holst discloses: "**The two sliding layers 4** can, if so desired, be embodied differently and **made of different materials**. One possibility, for example, is to have lower friction in the outer sliding layer than in the inner." Ex.1005[VonHolst], 6:6-10.

198. Therefore, claim 6 is obvious over Von Holst combined with Halldin and Puchalski.

7. Claim 8

a) "The helmet of claim 1, wherein a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head."

199. Von Holst combined with Halldin and Puchalski renders claim 1 obvious. Section X.B.2. *See* my discussion in Section X.B.2, which I incorporate here. Von Holst also discloses "a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head." Von Holst discloses that "the inner shell 3 is constructed from a harder, relatively thin outer layer 3" and a softer, relatively thick **inner layer 3'**." I show this **inner layer 3'** in annotated Figure 3b below:

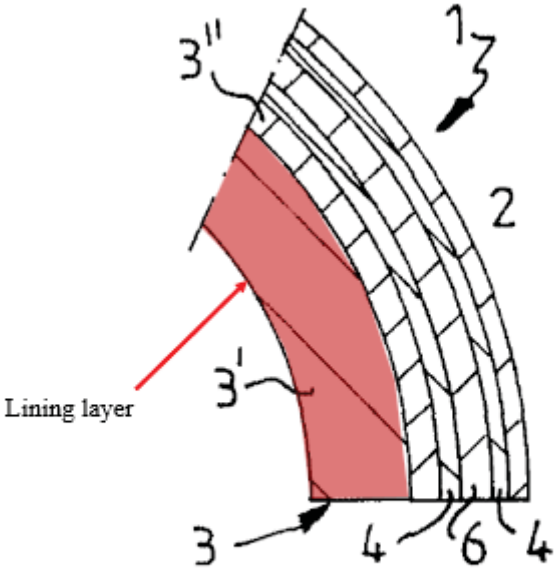


FIG.3b

Ex.1005[VonHolst], Fig. 3b. In Figure 3b of Von Holst, "the inner shell 3 is constructed in the same manner as in Fig. 3a." Ex.1005[VonHolst], 5:39-6:4; cl. 6.

Von Holst explains that "inner shell (3) is intended for contact with the head of the wearer," Ex.1005[VonHolst], 9:13-15, and includes both a "harder outer layer 3" and a softer **inner layer 3'**", which "can be made of…polyurethane foam or polystyrene." Ex.1005[VonHolst], 4:26-29, 7:26-30.

200. Thus, in my opinion, Von Holst combined with Halldin and Puchalski renders claim 8 obvious.

8. Claim 9

a) 9[preamble]: "Protective gear comprising:"

201. Von Holst discloses "[p]rotective gear." Von Holst discloses multiple embodiments of a "protective helmet," including a helmet in Figures 1-2, and then in Figure 3 a series of "variants" of the helmet from Figure 1. Ex.1005[VonHolst], 4:10-14. A helmet is a type of protective gear.

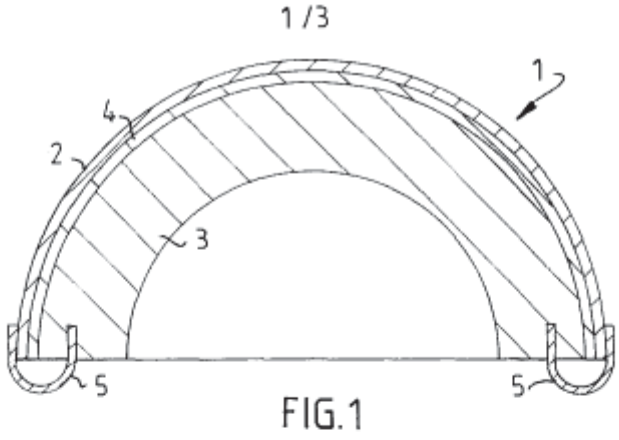


FIG.1

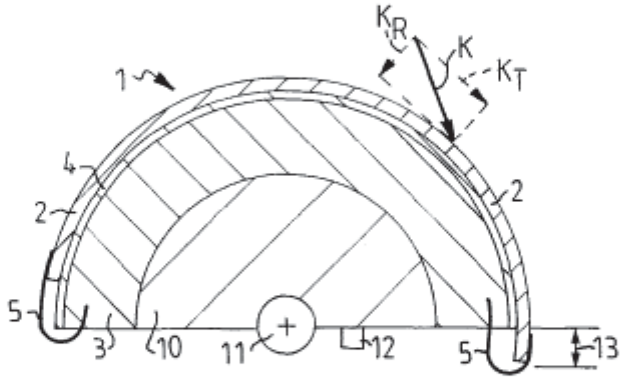


FIG.2

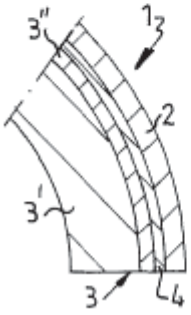


FIG.3a

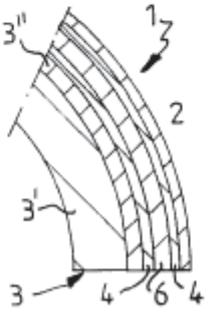


FIG.3b

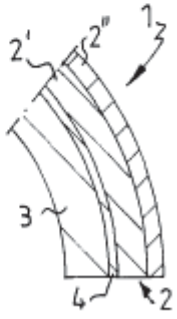


FIG.3c

Ex.1005[VonHolst], 4:10-14, Figs. 1-3.

b) 9[a]: "an outer shell layer;"

202. Von Holst discloses "an outer shell layer." Specifically, as shown in Figure 3b below, Von Holst discloses a helmet "constructed from an outer shell 2…." Ex.1005[VonHolst], 4:10-12, Figs. 1-3.

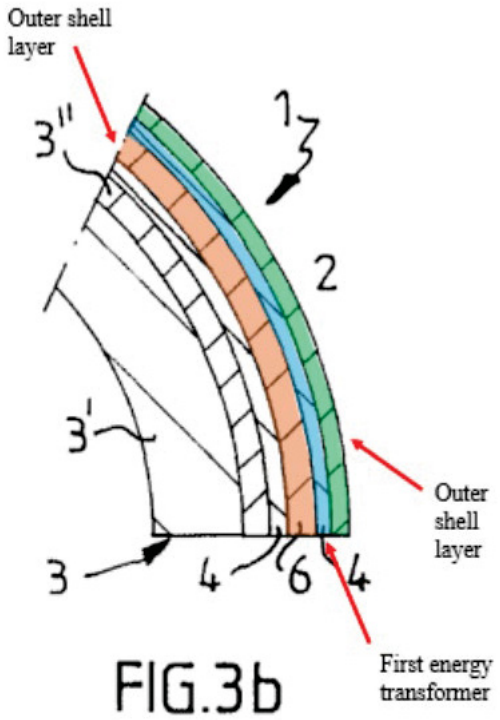


FIG.3b

Ex.1005[VonHolst], FIG. 3b

c) 9[b]: "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

203. In my opinion, Von Holst combined with Halldin discloses "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein

the shear mechanism includes a first energy transformer having a first absorptive/dissipative material" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.B.2.c). I note that the "inner conforming layer" in claim 9 is encompassed within the "inner shell layer" in claim 1. Specifically, claim 1 describes that its "inner shell layer" is "configured to conform to a human head," making the inner shell layer also an "inner conforming layer." Consistent with this understanding, claim 9 similarly states its "inner conforming layer" is "configured to conform to a human head." The '635 Patent's specification does not describe "conforming layer" or "conform" anywhere except the claims, and it does not provide any other discussion that would alter my understanding. To the extent there is any difference between "inner shell layer" and "inner conforming layer", in my view, both inner shell layer and inner conforming layer are taught by Von Holst.

d) 9[c] "the inner conforming layer configured to conform to a human head;"

204. In my opinion, Von Holst combined with Halldin discloses "the inner conforming layer configured to conform to a human head" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.B.2.d).

e) 9[d]: "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer

on the human head during rotational force impact while the outer shell layer is allowed to slide."

205. Von Holst combined with Puchalski teaches "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide" for the same reasons as I discuss above with respect to claim 1. Section X.B.2.e).

206. For all of the reasons discussed above, it is my view that claim 9 is obvious over Von Holst combined with Halldin and Puchalski.

9. Claim 10

a) "The protective gear of claim 9, wherein the shear mechanism is a shear layer."

207. Von Holst combined with Halldin and Puchalski renders claim 9 obvious. *See* my discussion in Section X.B.8, which I incorporate here. In my opinion, Von Holst combined with Halldin discloses "the shear mechanism is a shear layer." Specifically, Von Holst combined with Halldin discloses claim 10 for the same reasons as I discussed above with respect to claim 2. *See* my discussion in Section X.B.3 above, which I incorporate here.

208. Therefore, in my view, claim 10 is obvious over Von Holst combined with Halldin and Puchalski.

10. Claim 11

a) "The protective gear of claim 10, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer."

209. Von Holst combined with Halldin and Puchalski renders claim 10 obvious. *See* my discussion in Section X.B.9, which I incorporate here. In my opinion, Von Holst combined with Halldin teaches "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer." Specifically, Von Holst discloses claim 11 for the same reasons as I discussed above with respect to claim 3. *See* my discussion in Section X.B.4 above, which I incorporate here.

210. Therefore, in my view, claim 11 is obvious over Von Holst combined with Halldin and Puchalski.

11. Claim 12

a) "The protective gear of claim 11, wherein the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy

transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer."

211. Von Holst combined with Halldin and Puchalski renders claim 11 obvious. *See* my discussion in Section X.B.10, which I incorporate here. In my opinion, Von Holst combined with Halldin discloses "the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer." Specifically, Von Holst combined with Halldin discloses claim 12 for the same reasons as I discussed above with respect to claim 4. *See* my discussion in Section X.B.5 above, which I incorporate here.

212. Therefore, in my view, claim 12 is obvious over Von Holst combined with Halldin and Puchalski.

12. Claim 14

a) "The protective gear of claim 9, wherein the first absorptive/dissipative material comprises a fluid."

213. Von Holst combined with Halldin and Puchalski renders claim 9 obvious. *See* my discussion in Section X.B.8, which I incorporate here. In my

opinion, Von Holst discloses "the first absorptive/dissipative material comprises a fluid." Specifically, Von Holst discloses claim 14 for the same reasons as I discussed above with respect to claim 6. *See* my discussion in Section X.B.6 above, which I incorporate here.

214. Therefore, in my view, claim 14 is obvious over Von Holst combined with Halldin and Puchalski.

13. Claim 16

a) "The protective gear of claim 9, wherein the inner conforming layer is associated with a lining material configured to conform to a human head."

215. Von Holst combined with Halldin and Puchalski renders claim 9 obvious. *See* my discussion in Section X.B.8, which I incorporate here. In my opinion, Von Holst combined with Halldin teaches "the inner conforming layer is associated with a lining material configured to conform to a human head." Specifically, Von Holst discloses claim 16 for the same reasons as I discussed above with respect to claim 8. *See* my discussion in Section X.B.7 above, which I incorporate here.

216. Therefore, in my view, claim 16 is obvious over Von Holst combined with Halldin and Puchalski.

14. Claim 17

a) 17[preamble]: "A helmet comprising:"

217. In my opinion, Von Holst discloses "[a] helmet" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.B.2.a) and X.B.8.a).

b) 17[a]: "an outer shell layer;"

218. In my opinion, Von Holst discloses "an outer shell layer" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.B.2.b) and X.B.8.b).

c) 17[b]: "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

219. In my opinion, Von Holst combined with Halldin discloses "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.B.2.c) and X.B.8.c).

d) 17[c] "the inner conforming layer configured to conform to a human head;"

220. In my opinion, Von Holst combined with Halldin discloses "the inner conforming layer configured to conform to a human head" for the same reasons as I

discuss above with respect to claims 1 and 9. See my discussion in Sections X.B.2.d) and X.B.8.d).

e) 17[d]: "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

221. In my opinion, Von Holst combined with Puchalski discloses "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.B.2.e) and X.B.8.e).

222. For all of the reasons discussed above, it is my view that claim 17 is obvious over Von Holst combined with Halldin and Puchalski.

15. Claim 18

a) "The helmet of claim 17, wherein the shear mechanism is a shear layer."

223. Von Holst combined with Halldin and Puchalski renders claim 17 obvious. *See* my discussion in Section X.B.14, which I incorporate here. In my opinion, Von Holst combined with Halldin teaches "the shear mechanism is a shear layer." Specifically, Von Holst discloses claim 18 for the same reasons as I discussed above with respect to claims 2 and 10. *See my* discussion in Sections X.B.3 and X.B.9 above, which I incorporate here.

224. Therefore, in my view, claim 18 is obvious over Von Holst combined with Halldin and Puchalski.

16. Claim 19

a) "The helmet of claim 18, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer."

225. Von Holst combined with Halldin and Puchalski renders claim 18 obvious. *See* my discussion in Section X.B.15, which I incorporate here. Von Holst combined with Halldin discloses "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer." The combination discloses claim 19 for the same reasons as claims 3 and 11. *See* my discussion in Sections X.B.4 and X.B.10.

226. Therefore, it is my view that claim 19 is obvious over Von Holst combined with Halldin and Puchalski.

17. Claim 20

a) "The helmet of claim 19, wherein the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer."

227. Von Holst combined with Halldin and Puchalski renders claim 19 obvious. Section X.B.16 Von Holst combined with Halldin discloses "the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer". Von Holst combined with Halldin discloses claim 20 for the same reasons as I provided with respect to claims 4 and 12. *See* my discussion above in Sections X.B.5 and X.B.11.

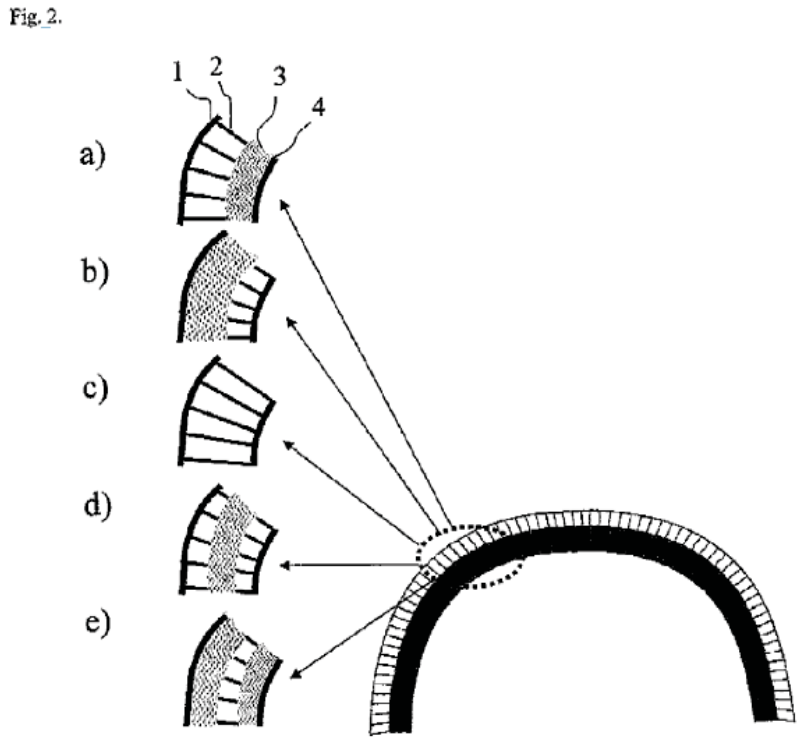
228. Therefore, it is my opinion that claim 20 is obvious over Von Holst combined with Halldin and Puchalski.

C. Ground 3: Claims 1-4, 6, 8-12, 14, and 16-20 are Obvious over Kleiven Combined with Puchalski

1. Claim 1

a) 1[preamble]: "A helmet comprising:"

229. Kleiven discloses "a helmet." For example, describing Figure 2 (reproduced below), Kleiven discloses that "spikes 2 can be placed in relation to the different layers of a helmet." Ex.1007[Kleiven], [0031].

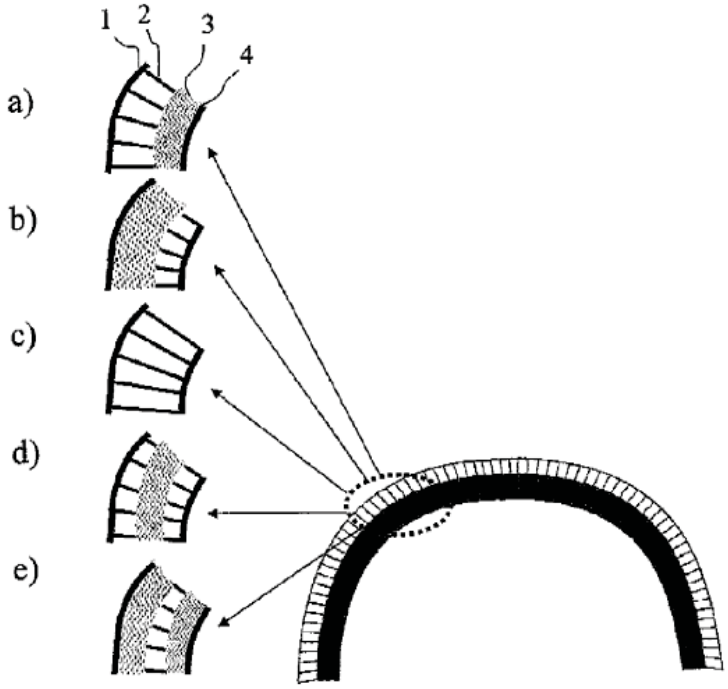


Ex.1007[Kleiven], [0031], Fig. 2. Figure 2 of Kleiven further describes multiple configurations of the layers of the helmet in Figures 2a through 2e.

b) 1[a]: "an outer shell layer;"

230. Kleiven discloses "an outer shell layer." For example, Figure 2 of Kleiven includes "outer…shell" 1, which Kleiven also refers to as an "outer…layer." Ex.1007[Kleiven], [0030]-[0031].

Fig. 2.



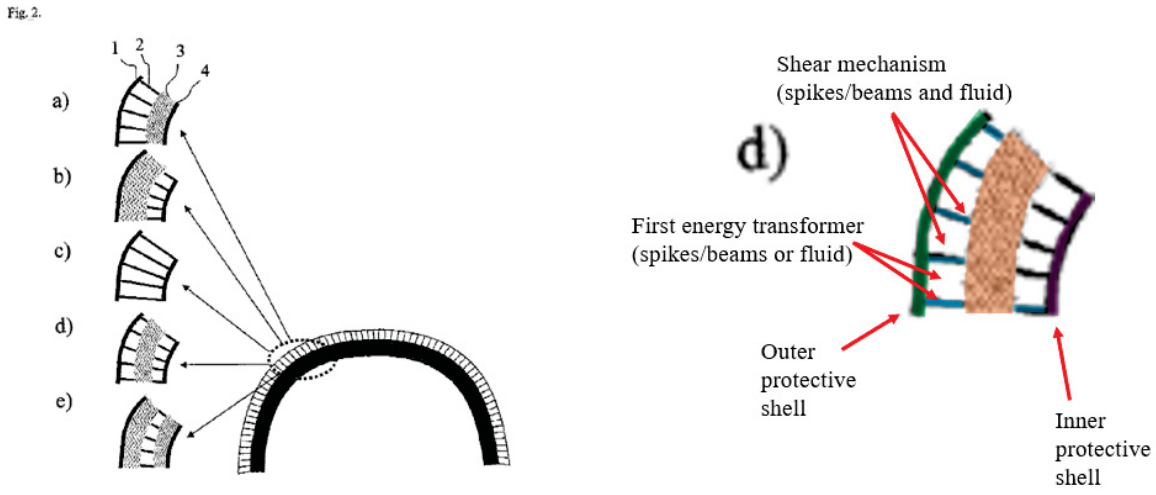
Ex.1007[Kleiven], [0031], Fig. 2.

c) 1[b]: "an inner shell layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

231. Kleiven discloses "an inner shell layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material."

232. Kleiven discloses an "inner shell layer" in the form of "**inner shell 4**". Ex.1007[Kleiven], [0031], Fig. 2.

233. Kleiven discloses inner and outer shell layers connected by a shear mechanism that includes a first energy transformer. Kleiven describes a shear mechanism in the form of components positioned between the outer and inner shells that enable shearing and allow relative sliding. This shear mechanism includes spikes/beams and fluid/air compartments, which connect Kleiven's inner and outer shells. For example, as I show in annotated Figure 2 of Kleiven, Kleiven discloses an **outer shell/layer 1 (the outer shell layer)**, an **inner shell layer 4**, and spikes/beams 2 with fluid/air compartments in between that enable shearing and sliding. Ex.1007[Kleiven], [0031] ("FIG. 2 shows an overview figure showing how the spikes 2 can be placed in relation to the different layers of a helmet."), [0040] (describing "fluid/air layer" 5 that "shears with little resistance" and "distributes the pressure in the radial direction on to other structures of the helmet"). The spikes/beams and fluid/air transform energy from impact force to movement that absorbs and dissipates the impact event. Kleiven discloses that its spikes/beams are "flexible, plasticizing, yielding or frangible in order to absorb/reduce the force of an impact towards the material." Ex.1007[Kleiven], [0048], [0062], [0020], [0002], Fig. 2. The spikes/beams transform energy from impact forces on the outer layer of the helmet to other types of energy by allowing relative sliding of surrounding layers that allows for absorption and dissipation of the impact.



Ex.1007[Kleiven], Fig. 2. Additionally, the fluid/air compartments transform energy through translational movement and viscous dissipation from fluid flow, which generate heat. Kleiven discloses: "It is noticeable that this fluid/air layer shears with little resistance while the fluid/air 5 at the same time distributes the pressure in the radial direction on to other structures of the helmet such as the energy absorbing internal liner 3." *Id.*, [0040], Fig.11. Therefore, the shear mechanism includes spikes/beams and fluid/air compartments, which serve to connect the inner and outer shells. Ex.1007 [Kleiven], [0039]-[0041], [0048], [0062], [0020], [0002]. As I discussed in Ground 1 with respect to Weber, connection per the '635 Patent may be indirect. *See* my discussion at Section X.A.2.c).

234. Kleiven discloses "a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first

energy transformer having a first absorptive/dissipative material." Kleiven discloses a shear mechanism comprising components such as spikes, beams, and fluid/air compartments, which enable shearing and allow the outer shell layer to slide relative to the inner shell layer. As discussed above, Kleiven describes its spikes/beams as "flexible, plasticizing, [or] yielding" elements that "give way" or shear to "permit displacement of the outer shell relative to the inner shell." Ex.1007 [Kleiven], [0048], [0062]. These spike/beam layers with surrounding fluid/air function similarly to layers 511 and 513 in Figure 5 of the '635 Patent. For example, the '635 Patent describes:

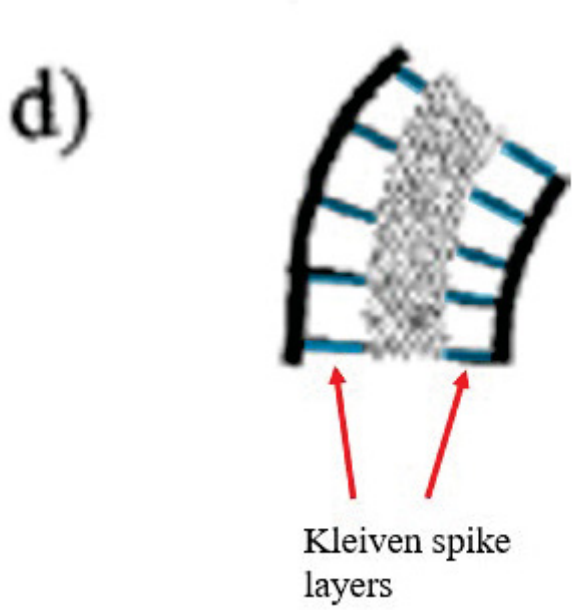
> "In some examples, **a mechanical transformer layer** is provided between each pair of adjacent shells. The mechanical transform[er] may use **a shear truss-like structure connecting an outer shell and an inner shell that dampens any force or impact**. In some examples, shear truss structure layers connect an outer shell to a middle shell and the middle shell to an inner shell. According to various embodiments, the middle shell or center shell may **slide relative to the inner shell** and reduce the movement and/or impact imparted on an outer shell."

Ex.1001[USP635], 6:29-38; *see also id*., 6:29-45; *id.*, Fig. 5, 9:6-33 ("elastomeric trusses" in the form of "energy and impact transformer layers 511 and 513 [that] may also include energy dampening/absorbing fluids"). To a POSA the spikes/beams 2 and surrounding fluid/air of Kleiven are the same as the "shear truss-

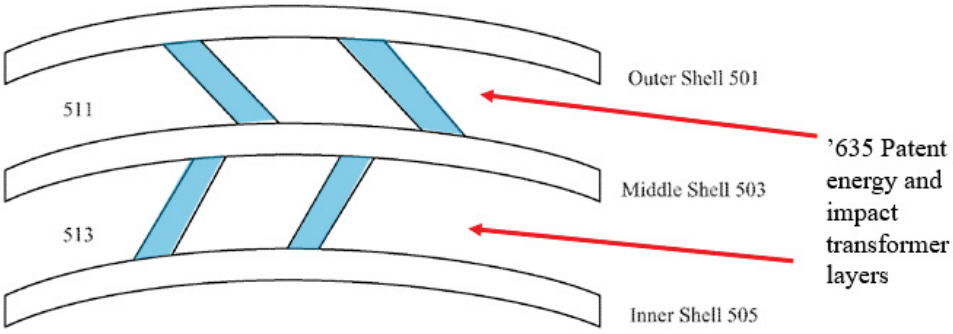
like structure" of the '635 Patent with surrounding fluid. The '635 Patent describes and depicts an embodiment of such "a shear truss-like structure[s]", which it calls energy impact and transformer layers 511 and 513: "In particular embodiments, the energy and impact transformer **layers 511 and 513** may include **thin elastomeric trusses** between the shells in a comb structure. The energy and impact transformer layers 511 and 513 may also include energy dampening/absorbing fluids or devices." Ex.1001[USP635], 9:31-33; *see also id*., 9:5-14 ("Energy and impact **transformer layer 511** residing between shells 501 and 503 **may allow shell 501 to move and/or slide** with respect to middle shell 503.… Similarly, **middle shell 503 can move and slide with respect to inner shell 505**."); *id*., 11:3-7 ("[I]mpact transformer layer 609 allows the **outer shell** 603 and the middle shell 607 **to move relative to the inner shell** 611."). As I show below in annotated Figure 2d of Kleiven and Figure 5 of the '635 Patent, the layers of spikes/beams 2 with surrounding fluid/air of Kleiven are

very similar (if not the same) as the layer of trusses with surrounding fluid ("energy and impact transformer") in the '635 Patent. [12]

[12] To the extent Patent Owner suggests that Kleiven's spikes/beams are not trusses as the '635 patent uses the term (or materially different in any other way) due to the spike layers not being depicted as intersecting the layers diagonally, I note that to a person of ordinary skill in the art as of 2011 (and since) "trusses" refer to a structure or structures in a framework with members, which can consist of, for example, rafters, posts, and/or struts, that supports another structure, (in general application, this would include a roof, a bridge, or another structure). Although early trusses were typically constructed using diagonally intersecting members, other common arrangements of trusses, such as Vierendeel trusses (known since at least the 19th century), utilize only parallel and perpendicular intersection members. Ex.1021[Pons-Poblet], 2.



Ex.1007[Kleiven], Fig. 2.



Ex. 1001[USP635], Fig. 5; *see* Ex.1013 [Knight-162-FH], 147 (referring to elastomeric trusses in Figure 5).

235. In addition, I understand that during prosecution of a different patent in the same patent family ('162 patent) as the '635 Patent, Applicant stated that "thin

elastomeric trusses" are "depicted in Figure 5 of the application as filed." Ex.1013[Knight-162-FH], 147.[13] I have reviewed the relevant portions of the prosecution history of the '162 patent and agree that Figure 5 of the '635 Patent (which is the same figure as Figure 5 of the '162 patent) depicts the elastomeric trusses.

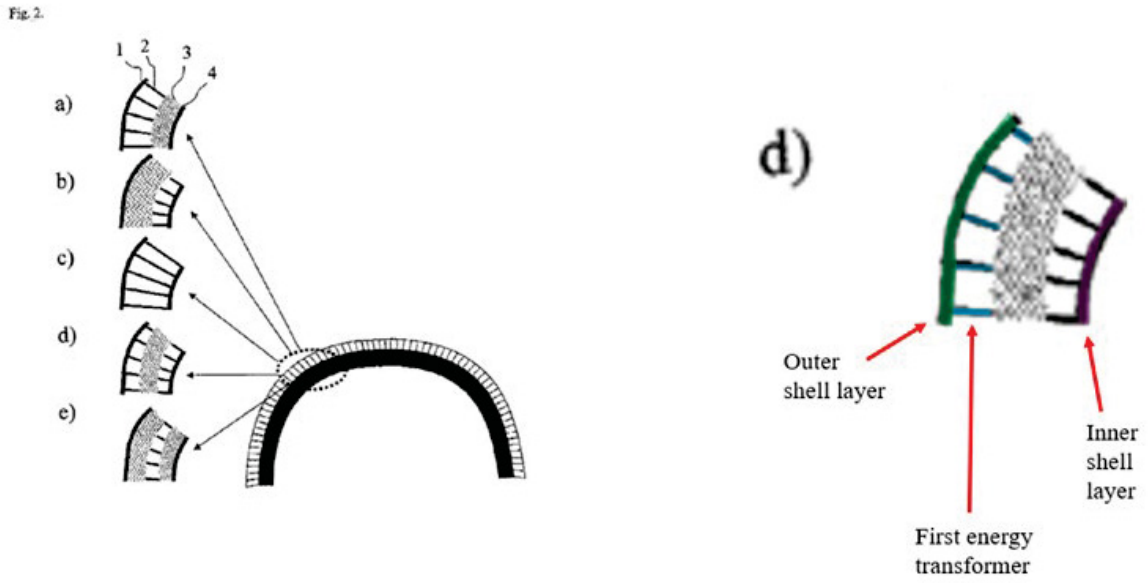
236. As another example, Kleiven discloses fluid compartments positioned between spikes, filled with a fluid such as air, that also function as a shear mechanism. The '635 Patent explains that its "energy and impact transformer layers 511 and 513 may also include energy dampening/absorbing **fluids** or devices," Ex.1001[USP635], 9:31-33, and that "the amount of movement and/or **sliding**

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[13] I understand that at the same time that Applicant was prosecuting the application that resulted in the granted '635 Patent, the Applicant was also prosecuting another U.S. application—No. 13/554,563—and that the '563 application claims priority to the same provisional application as the '635 Patent. Ex.1013**[**Knight-162-FH**],** 48. I understand that this '563 application issued as U.S. Patent No. 10,238,162 ('162 patent). I also understand that Applicant filed the '563 application on the same day that it filed the application that is the parent application of the '635 Patent (U.S. Application No. 13/554,471, now U.S. Patent No. 8,863,319, Ex.1030).

depends on the viscosity of **fluid** in the energy and impact transformer layers 511 and 513." Ex.1001[USP635], 9:16-18. Similar to the '635 Patent, Kleiven also discloses compartments that are between the beams/spikes 2 in the beam/spike layer that can be filled with fluid (*e.g.*, air), which allow the outer shell/layer to slide relative to the inner/shell layer of Kleiven's helmet. Ex.1007[Kleiven], [0039]-[0041]. For example, Kleiven discloses: "FIG. 11 illustrates the design and energy absorption behavior of a helmet for the option where inclusion of **air compartments** is added to or included separately (**with** or without **spikes**) using a relatively stiff plastic outer shell. Note that the helmet design is seen in a mid cross section. It is noticeable that **this fluid/air layer shears** with little resistance while the fluid/air 5 at the same time distributes the pressure in the radial direction on to other structures of the helmet such as the energy absorbing internal liner 3." Ex.1007[Kleiven], [0040], [0065] ("air/fluid can also be allowed to flow through small channels between the compartments…."), Figs.10-12; *see also* Ex.1001[USP635], 6:46-63 ('635 Patent). Kleiven's compartments between spikes/beams in the spike/beam layer that are filled with fluid (*e.g.*, air) also shear to allow the outer shell layer to slide relative to the inner shell layer and transform energy. Ex.1007[Kleiven], [0039-41] ("fluid/air layer **shears**"), [0047], Figs.10-12; Ex.1001[USP635], 6:29-45.

237. As I discussed above in Section X.A.2.d), to the extent Patent Owner argues that shear mechanism requires a middle shell/layer (in my opinion it does not), Kleiven discloses this in Figure 2(d). Kleiven discloses an energy absorbing middle layer associated with inner and outer layers of spikes/beams and fluid/air compartments. Kleiven's middle "**energy absorbing foam 3**" with "inserts that attach the spikes to the shells/layers" together with the spikes/beams and fluid compartments would render this obvious. Ex.1007[Kleiven], [0031], [0041]. Kleiven's middle foam layer made of, *e.g.*, "expanded polystyrene and expanded polypropylene," is a middle shell. Ex.1007[Kleiven], [0048]. *See* my discussion in Section X.A.2.b) with respect to Weber's outer liner, which applies in the same way to Kleiven's intermediate layer. In this way, the inserts that are part of the shear mechanism are between the spikes/beams and the energy absorbing foam 3 as well as between the spikes/beams and the outer shell layer.



Ex.1007[Kleiven], Fig. 2.



Ex.1007[Kleiven], Fig. 12a (showing spikes in black and inserts in horizontal lines that attach the spikes to the shell layers of the helmet). To a POSA this middle layer with the inserts for spikes provides a structure to physically connect the spikes (with the fluid compartments/walls) to the outer shell layer while allowing the energy transformers to shear.

238. Kleiven's spikes/beams are made of an "absorptive/dissipative material." Kleiven discloses that its spikes/beams are "flexible, plasticizing, yielding or frangible in order to **absorb/reduce the force of an impact** towards the material." Ex.1007[Kleiven], [0048], Fig. 2. Kleiven's spikes/beams' mechanical deformation thus absorbs and/or dissipates energy from the impact force. Kleiven explains that: "thin **spikes [] reduce** angular acceleration and this design further reduces the **angular forces significantly**, to approximately 50% compared to a regular helmet design where the outer shell is glued to the liner (see FIG. 9)." Ex.1007[Kleiven], [0011][14]. Kleiven's beams/spikes (or "thin spikes") are also absorptive/dissipative material because they allow for relative sliding between layers/shells of the helmet which absorbs and/or dissipates energy through movement and heat.

239. In my opinion, the fluid (*e.g.*, air/oil) within the fluid compartments in the beam/spike layer of Kleiven's helmet are also an "absorptive/dissipative material." For example, Kleiven discloses:

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[14] I note that to a POSA the "thin spikes" described with reference to Kleiven's Figure 9 are exemplary spikes that would be used as the spikes/beams in any of Kleiven's embodiments, including in the helmet embodiments shown in Figure 2.

> FIG. 11 illustrates the design and energy absorption behavior of a helmet for the option where **inclusion of air compartments** is added to or included separately (**with** or without **spikes**) using a relatively stiff plastic outer shell. Note that the helmet design is seen in a mid cross section. It is noticeable that **this fluid/air layer** shears with little resistance while the fluid/air 5 at the same time distributes the pressure in the radial direction on to other structures of the helmet such as the energy absorbing internal liner 3.

Ex.1007[Kleiven], [0040].

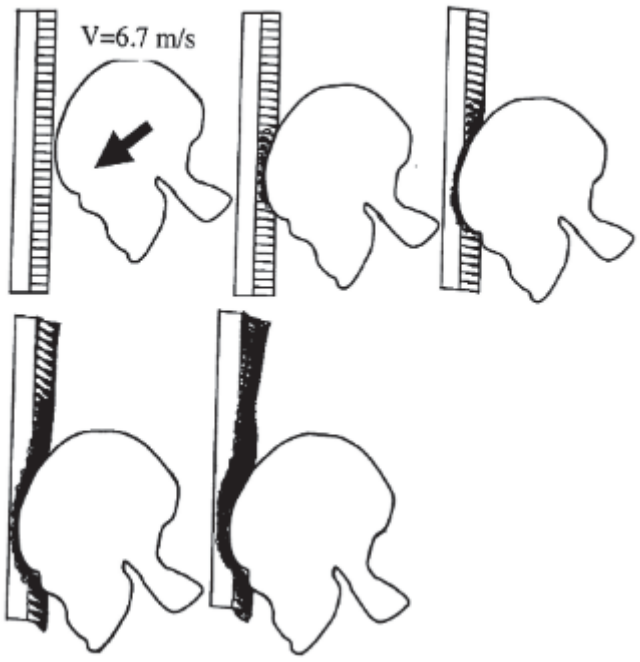
240. To a POSA upon impact, the fluid/air will absorb and/or dissipate the energy from the force of that impact via compression, which increases internal pressure, and through displacement, which dissipates energy via resistive flow, and generation of heat through these processes. I note that the '635 Patent itself states that a fluid and a gel are "absorptive/dissipative materials": "The space between the outer shell, the middle shell, and the inner shell can be **filled with absorptive/dissipative material such as fluids and gels**." Ex.1001[USP635], 6:60-63; *see also id*., 6:57-60.

241. Kleiven's spikes/beams and surrounding fluid compartments are each absorptive/dissipative material that allows for relative sliding that absorbs and/or dissipates energy through movement and heat.

d) 1[c]: "the inner shell layer configured to conform to a human head;"

242. Kleiven discloses "the inner shell layer configured to conform to a human head." For example, as shown in Figure 2, Kleiven's inner shell layer is contoured to fit the shape of a human head, while Figures 3 and 4 show how it compresses to mold around the head upon impact. Ex.1007[Kleiven], Figs. 2-4. Kleiven further discloses that earlier helmet designs "improve[] the capacity of the headgear to conform to the head…." Ex.1007[Kleiven], [0014].

Fig. 3.



Ex.1007[Kleiven], Fig. 3.

e) 1[d]: "a chin strap attached to the inner shell layer to maintain the position of the inner shell layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

243. Kleiven combined with Puchalski renders obvious "a chin strap attached to the inner shell layer to maintain the position of the inner shell layer on the human head during rotational force impact while the outer shell layer is allowed to slide." As I discussed in Section X.A.2.e), Puchalski discloses a chin-strap (*e.g.*, with a two-piece design) for a helmet. For example, Puchalski teaches that "[a]lthough not essential, most preferably, the helmet **chin straps 16** are secured to the peripheral edge of the **inner panel 126**, along each of its sides." Ex.1011[Puchalski], 12:1-3; Figs. 9-10.

Fig. 9

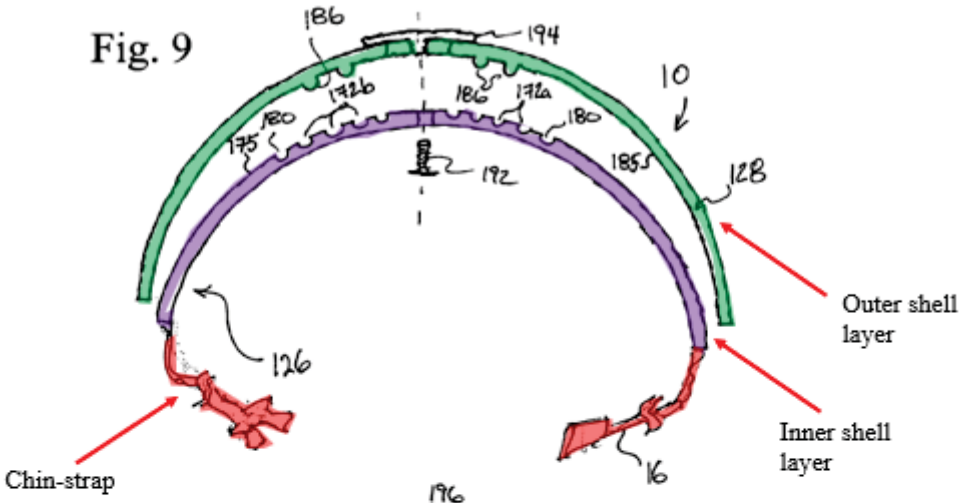
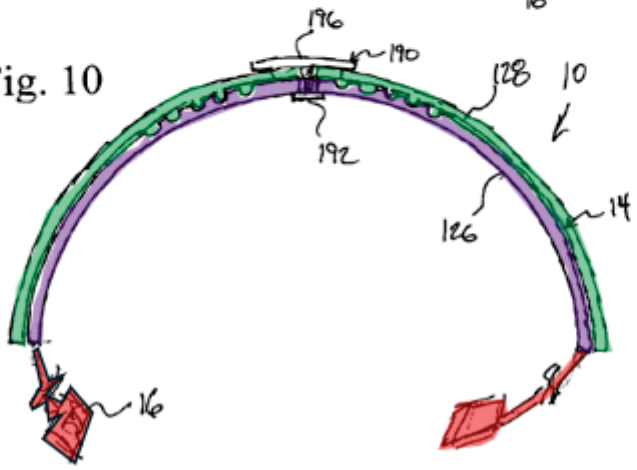


Fig. 10



Ex.1011[Puchalski], Figs. 9, 10.

244. In my opinion, it would have been obvious to attach Puchalski's chin-strap to the periphery of the inner shell of Kleiven's helmet. To a POSA Kleiven's helmet with a chin-strap added to the inner shell layer still allows the outer shell layer to slide relative to the inner shell layer in the helmet.

245. In my opinion, a POSA would have been motivated to modify Kleiven's helmet with a chin-strap of Puchalski's helmet and would have had a

reasonable expectation of success in doing so. Kleiven and Puchalski are analogous art. A POSA would also have appreciated that Puchalski's chin-strap is most preferably attached to on an inner shell layer so that a position of the helmet on the wearer's head would be maintained when the outer shell layer slides relative to the inner shell layer. *See* also my discussion on this point in Section X.A.2.e) with respect to Ground 1. In my view, it would have been an obvious design choice to add a chin-strap on the inner shell layer that helps conform and be secured to the wearer's head, while still allowing the outer shell layer to slide upon rotational impact relative to the inner shell layer.

246. As I discussed in Section X.A.2.e) with respect to Ground 1, there are a finite number of locations for attaching a chin-strap because it has to be attached to a structural feature: the inner shell layer, intermediate shell layer, or outer shell layer. A POSA would have been motivated to try each of these finite options. Also, to ensure a position that is consistent and provides a proper fit of the chin-strap, a

POSA would also not have been motivated to select a shell layer that moves relative to the wearer's head.[15]

247. In my opinion, a POSA would have had a reasonable expectation of success in modifying Kleiven's helmet with the inclusion of Puchalski's chin-strap. Puchalski discloses a chin-strap along an inner shell layer of a helmet that has multiple sliding layers with success. It would have been simply a matter of routine experimentation, and conventional, to add/configure Puchalski's chin-strap for attachment to inner shell layer of Kleiven's helmet.

248. Therefore, in my opinion, claim 1 is obvious over Kleiven combined with Puchalski.

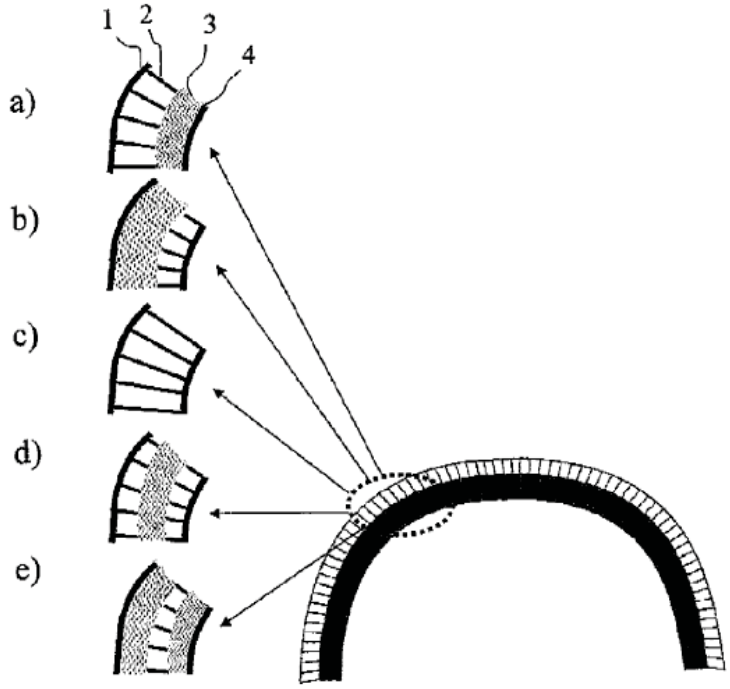
2. Claim 2

a) "The helmet of claim 1, wherein the shear mechanism is a shear layer."

[15] I note that a POSA would not have attached a chin-strap to Kleiven's spikes/beams layer because this would interfere with the functionality of the spikes/beams (*e.g.*, providing a dampening effect) and would also not provide for a secure attachment because the compartments between the spikes/beams are filled with fluid/air.

249. Kleiven combined with Puchalski renders claim 1 obvious. *See* Section X.C.1. Kleiven discloses that "the shear mechanism is a shear layer." Kleiven's shear layer includes spikes/beams and fluid/air. Kleiven's beams/spikes as well as fluid compartments are arranged in a "spike layer" 2. Ex.1007[Kleiven], [0020], [0031], [0039-41], [0048], Figs. 1-2; *see also* my discussion in Section X.C.1.d) with respect to claim 1. For example, Figure 2 of Kleiven which I reproduce below shows how the spikes/beams are arranged as a layer 2.

Fig. 2.



Ex.1007[Kleiven], Fig. 2, [0031. Kleiven's fluid/air compartments are also a "fluid/air layer." Ex.1007[Kleiven], [0040].

250. In the alternative, in Figure 2(d), Kleiven's middle foam layer along with surrounding spikes and fluid compartments is a shear layer. Ex.1007[Kleiven], [0031], Fig. 2.

251. Therefore, it is my opinion that claim 2 is obvious over Kleiven combined with Puchalski.

3. Claim 3

a) "The helmet of claim 2, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer."

252. Kleiven combined with Puchalski renders claim 2 obvious. *See* Section X.C.2. Kleiven discloses that "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer." As discussed in Sections X.C.1.c) and X.C.2, Kleiven's shear layer 2, which includes spikes/beams and fluid/air compartments, is connected to the outer shell through the first energy transformer formed by these components within the shear layer. Ex.1007[Kleiven], [0048],

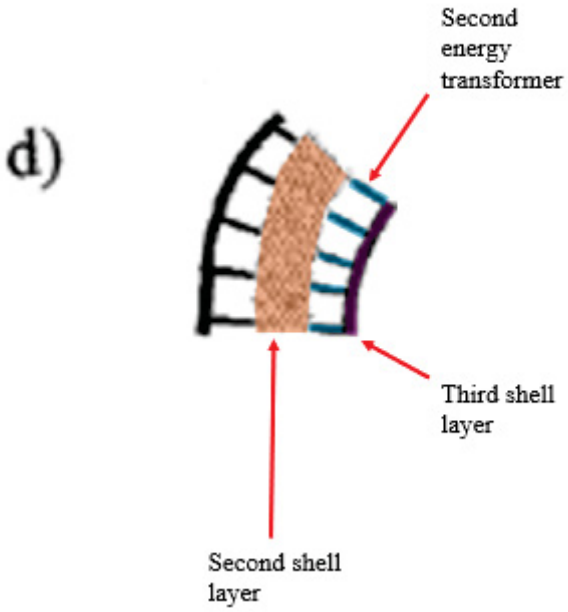
[0062], [0020], [0002], Fig. 2. Kleiven's first energy transformer also includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer as Section X.C.1.c) discusses. Kleiven's first energy transformer—i.e., the spike/beam layer or fluid/air—absorbs energy from forces imparted onto the outer shell layer. Ex.1007[Kleiven], [0002], [0020]. Kleiven's spikes/beams absorb energy upon impact because they are "flexible, plasticizing, [or] yielding" and "give way" or shear and "permit displacement of the outer shell relative to the inner shell." Ex.1007[Kleiven], [0048], [0062]. Kleiven also discloses compartments that are between the beams/spikes 2 in the beam/spike layer that can be filled with fluid (*e.g.*, air), which absorb energy upon impact and allow the outer shell/layer to slide relative to the inner/shell layer of Kleiven's helmet. Ex.1007[Kleiven], [0039]-[0041], id., [0040] ("this fluid/air layer shears").

253. Thus, it is my opinion that claim 3 is obvious over Kleiven combined with Puchalski.

4. Claim 4

a) "The helmet of claim 3, wherein the inner shell layer is connected to the shear layer, the inner shell layer configured to conform to a human head, the inner shell layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer."

254. Kleiven combined with Puchalski renders claim 3 obvious. *See* Section X.C.3. Kleiven teaches that "the inner shell layer is connected to the shear layer, the inner shell layer configured to conform to a human head, the inner shell layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer." As I show below in annotated Figure 2d of Kleiven, Kleiven discloses a helmet that has an **inner shell layer 4**, **energy absorbing foam 3**, and **inner spike/beam layer 2** (spikes/beams) that have fluid(air) compartments.



Ex.1007[Kleiven], [0031], Fig. 2(d).

255. **Inner shell 4** is connected to **energy absorbing foam 3** through **inner spike/beams** and the air pockets/compartments in the same way that **energy absorbing foam 3** is connected to **outer shell 1** through outer spike/beams and its surrounding fluid/air compartments (see Section X.C.1.c)). As I discussed in Section X.C.1.c), Kleiven discloses and shows in Figure 2d an inner spike/beam layer 2 (having spikes/beams and fluid compartments). The second energy transformer is the inner spikes/breams or the associated air compartments. This second energy transformer includes absorptive/dissipative material in the same way outer spike/beams or air compartments do, as I discussed in Section X.C.1.c). *See* my discussion above in Section X.C.1.c). Accordingly, at least some force imparted onto an outer shell layer would travel through the outer sliding layer and the energy absorbing foam to the second energy transformer, which would absorb energy in the same way as the first energy transformer. *See, e.g.*, Ex.1007[Kleiven], [0020] (purpose of spikes is to "reduc[e] the force from an oblique impact against e.g. the head" and "to give way after a tangential/rotational impact and thereby efficiently reduce the negative effects of such an impact on e.g. the brain"), [0048] (spikes are "flexible, plasticizing, yielding or frangible in order to absorb/reduce the force of an impact").

256. Thus, it is my opinion that claim 4 is obvious over Kleiven combined with Puchalski.

5. Claim 6

a) "The helmet of claim 1, wherein the first absorptive/dissipative material comprises a fluid."

257. Kleiven combined with Puchalski renders claim 1 obvious. Section X.C.1. Kleiven teaches "the first absorptive/dissipative material comprises a fluid." As I discussed in Section X.C.1.c), Kleiven's spike/beam layer includes a "fluid/air layer" that "shears with little resistance…[and] distributes the pressure in the radial direction." Ex.1007[Kleiven], [0039-40]. Kleiven's spikes/beams with surrounding fluid/air compartments allow the outer shell layer to slide relative to the inner shell layer. Section X.C.1.c).

258. Thus, it is my opinion that claim 6 is obvious over Kleiven combined with Puchalski.

6. Claim 8

a) "The helmet of claim 1, wherein a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head."

259. Kleiven combined with Puchalski renders claim 1 obvious. Section X.C.1. Kleiven combined with Puchalski teaches "a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head."

A POSA would have been motivated to modify Kleiven with Puchalski (with a reasonable expectation of success) which together disclose "a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head." Puchalski describes "[a] helmet…includ[ing] a shell contoured to the shape of the user's head, with cushioning along at least part of the shell interior and a chinstrap." Ex.1011[Puchalski], Abstract; *id.*, cl. 9 ("The helmet of claim 1 further including impact absorbing cushioning secured to an inner surface of said shell, said cushioning being resiliently compressible so as to compress with any movement of said first portion relative to said second portion."). Additionally, Puchalski teaches that "padding or cushioning [(i.e., "a lining layer")] may also be provided along the inside of the shell for increased comfort, better fit and to assist in the absorption of any impact forces." Ex.1011[Puchalski], 1:52-55. Puchalski's padding or cushioning is "a lining layer" that is connected to the inner surface of the inner shell layer/layer and is located between the inner shell layer/layer and the wearer's head.

260. In my opinion, a POSA would have been motivated to combine Kleiven and Puchalski by adding the cushioning or padding of Puchalski to the inner shell layer of Kleiven's helmet. These two references are analogous to the challenged claims as they are in same/similar fields and are directed to the same problem with

helmet design (failure to address rotational impact) and arrive at the same solution for improving helmet design and safety by using sliding layers to address impact/injuries. Kleiven explains that a "design with foam pillows improves the capacity of the headgear to conform to the head…." Ex.1007[Kleiven], [0014]. To the extent Kleiven does not explicitly disclose a "lining layer", Puchalski provides those details, including that "strips of resiliently compressible foam cushioning" "assists in maintaining the shell [] comfortably in the correct position on top of the user's head [] and furthermore, advantageously acts to assist in the absorption of impact forces." Ex.1011[Puchalski], 7:34-39; *see also id.*, 1:52-55. In my opinion, a POSA would have been motivated to add to Kleiven's helmet Puchalski's comfort lining layer (*i.e.*, its padding/cushioning) to achieve increased comfort and additional impact-force absorption. In my view, a POSA would have found it obvious to combine Kleiven's helmet with a lining layer of Puchalski as a matter of routine implementation since it is a straightforward and predictable combination of known elements according to known methods to yield predictable results. It is also clear that Kleiven's helmet was ready for improvement, using known techniques, by using Puchalski's lining layer (cushioning/padding) attached to the inner shell layer and a POSA would have improved Kleiven's helmet in the same way as Puchalski's helmet was improved with its padding/cushioning.

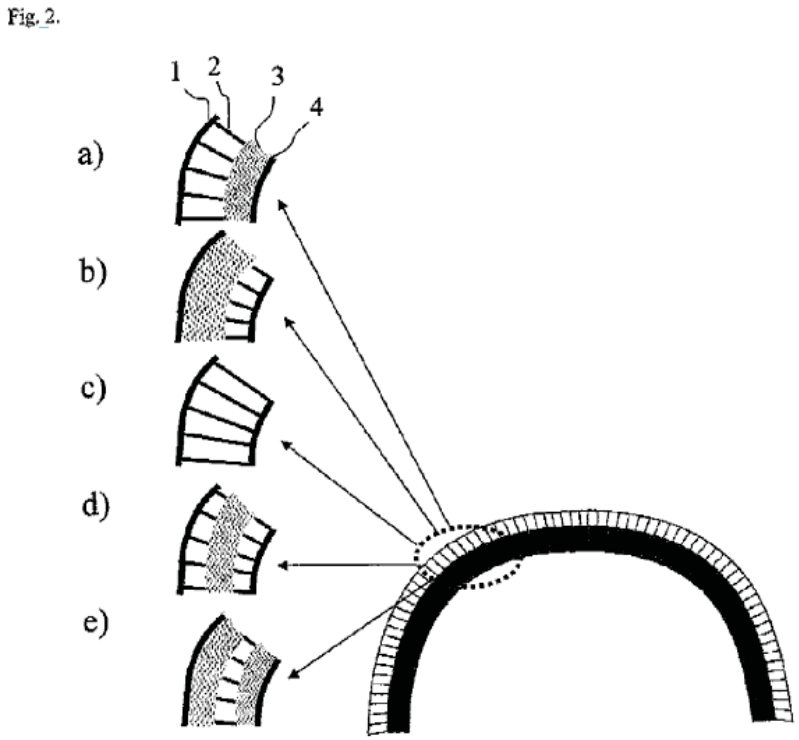
261. Moreover, Kleiven itself explains that "it is to be realized that the optimum dimensional relationships for the parts of the invention, to include variations in size, materials, shape, form, function and manner of operation, assembly and use, are deemed **readily apparent and obvious to one skilled in the art**." Ex.1007[Kleiven], [0069]; *see also id*., [0070]. Therefore, Kleiven itself states it would have been obvious to make various modifications to its helmet by combining known elements and making improvements using known techniques.

262. It is also my opinion that a POSA would have reasonably expected success in modifying Kleiven's inner shell layer by adding the cushioning/padding lining layer of Puchalski. As I explained above, Kleiven discloses benefits of headgear (such as a helmet) that is designed to conform to the wearer's head. Ex.1007[Kleiven], [0014]. In my opinion, as a matter of routine implementation, a POSA would have known how to use/configure Puchalski's liner (cushioning/padding) layer specifically for Kleiven's helmet design (or any helmet at the time for that matter), especially because Puchalski's lining layer is located in a place on the helmet (attached to the inner shell layer) that also exists in Kleiven's helmet (which also has an inner shell layer).

7. Claim 9

a) 9[preamble]: "Protective gear comprising:"

263. Kleiven discloses "protective gear." For example, describing Figure 2 (reproduced below), Kleiven discloses that "spikes 2 can be placed in relation to the different layers of a helmet." Ex.1007[Kleiven], [0031]. A helmet is a type of protective gear.



Ex.1007[Kleiven], [0031], Fig. 2. Figure 2 of Kleiven further describes multiple configurations of the layers of the helmet in Figures 2a through 2e.

b) 9[a]: "an outer shell layer;"

264. In my opinion, Kleiven discloses "an outer shell layer" for the same reasons as I discuss above with respect to claim 1. *See* my discussion in Section X.C.1.a).

c) 9[b]: "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

265. In my opinion, Kleiven discloses "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.C.1.c). I note that the "inner conforming layer" in claim 9 is encompassed within the "inner shell layer" in claim 1. Specifically, claim 1 describes that its "inner shell layer" is "configured to conform to a human head," making the inner shell layer also an "inner conforming layer." Consistent with this understanding, claim 9 similarly states its "inner conforming layer" is "configured to conform to a human head." The '635 Patent's specification does not describe "conforming layer" or "conform" anywhere except the claims, and it does not provide any other discussion that would alter my understanding. To the extent there is any difference between "inner shell layer" and "inner conforming layer", in my view, both inner shell layer and inner conforming layer are taught by Kleiven.

d) 9[c] "the inner conforming layer configured to conform to a human head;"

266. In my opinion, Kleiven discloses "the inner conforming layer configured to conform to a human head" for the same reasons as I discuss above with respect to claim 1. *See* my discussion in Section X.C.1.d).

e) 9[d]: "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

267. In my opinion, Kleiven combined with Puchalski discloses "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.C.1.e).

268. For all of the reasons discussed above, it is my view that claim 9 is obvious over Kleiven combined with Puchalski.

8. Claim 10

a) "The protective gear of claim 9, wherein the shear mechanism is a shear layer."

269. Kleiven combined with Puchalski renders claim 9 obvious. Section X.C.7. Kleiven discloses "the shear mechanism is a shear layer." Kleiven discloses claim 10 for the same reasons as I discussed above with respect to claim 2. *See my* discussion in Section X.C.2 above, which I incorporate here.

270. Therefore, in my view, claim 10 is obvious over Kleiven combined with Puchalski.

9. Claim 11

a) "The protective gear of claim 10, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer."

271. Kleiven combined with Puchalski renders claim 10 obvious. Section X.C.8. Kleiven discloses "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer." Specifically, Kleiven discloses claim 11 for the same reasons as I discussed above with respect to claim 3. *See* my discussion in Section X.C.3 above, which I incorporate here.

272. Therefore, in my view, claim 11 is obvious over Kleiven combined with Puchalski.

10. Claim 12

a) "The protective gear of claim 11, wherein the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the

inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer."

273. Kleiven combined with Puchalski renders claim 11 obvious. Section X.C.8. Kleiven discloses "the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer." Specifically, Kleiven discloses claim 12 for the same reasons as I discussed above with respect to claim 4. *See* my discussion in Section X.C.4 above, which I incorporate here.

274. Therefore, in my view, claim 12 is obvious over Kleiven combined with Puchalski.

11. Claim 14

a) "The protective gear of claim 9, wherein the first absorptive/dissipative material comprises a fluid."

275. Kleiven combined with Puchalski renders claim 9 obvious. Section X.C.8. Kleiven discloses "the first absorptive/dissipative material comprises a fluid." Specifically, Kleiven discloses claim 14 for the same reasons as I discussed

above with respect to claim 6. *See my* discussion in Section X.C.5 above, which I incorporate here.

276. Therefore, in my view, claim 14 is obvious over Kleiven combined with Puchalski.

12. Claim 16

a) "The protective gear of claim 9, wherein the inner conforming layer is associated with a lining material configured to conform to a human head."

277. Kleiven combined with Puchalski renders claim 9 obvious. Section X.C.7. In my opinion, Kleiven combined with Puchalski discloses "the inner conforming layer is associated with a lining material configured to conform to a human head." Specifically, Kleiven combined with Puchalski discloses claim 16 for the same reasons as I discussed above with respect to claim 8. *See my* discussion in Section X.C.6 above, which I incorporate here.

278. Therefore, in my view, claim 16 is obvious over Kleiven combined with Puchalski.

13. Claim 17

a) 17[preamble]: "A helmet comprising:"

279. In my opinion, Kleiven discloses "[a] helmet" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.C.1.a) and X.C.7.a).

b) 17[a]: "an outer shell layer;"

280. In my opinion, Kleiven discloses "an outer shell layer" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.C.1.b) and X.C.7.b).

c) 17[b]: "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

281. In my opinion, Kleiven discloses "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.C.1.c) and X.C.7.c).

d) 17[c] "the inner conforming layer configured to conform to a human head;"

282. In my opinion, Kleiven discloses "the inner conforming layer configured to conform to a human head" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.C.1.d) and X.C.7.d).

e) 17[d]: "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

283. In my opinion, Kleiven combined with Puchalski discloses "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.C.1.e) and X.C.7.e).

284. For all of the reasons discussed above, it is my view that claim 17 is obvious over Kleiven combined with Puchalski.

14. Claim 18

a) "The helmet of claim 17, wherein the shear mechanism is a shear layer."

285. Kleiven combined with Puchalski renders claim 17 obvious. Section X.C.13. In my opinion, Kleiven discloses "the shear mechanism is a shear layer." Specifically, Kleiven discloses claim 18 for the same reasons as I discussed above with respect to claims 2 and 10. *See* my discussion in Sections X.C.2X.A.3 and X.C.8 above, which I incorporate here.

286. Therefore, in my view, claim 18 is obvious over Kleiven combined with Puchalski.

15. Claim 19

a) "The helmet of claim 18, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer,

wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer."

287. Kleiven combined with Puchalski renders claim 18 obvious. Section X.C.14. Kleiven discloses "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer." Kleiven discloses claim 19 for the same reasons as claims 3 and 11. *See* my discussion in Sections X.C.3 and X.C.9.

288. Therefore, it is my view that claim 19 is obvious over Kleiven combined with Puchalski.

16. Claim 20

a) "The helmet of claim 19, wherein the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer."

289. Kleiven combined with Puchalski renders claim 19 obvious. Kleiven discloses "the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming

layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer". Kleiven discloses claim 20 for the same reasons as I provided with respect to claims 4 and 12. *See* my discussion above in Sections VI, X.C.4 and X.C.10.

290. Therefore, it is my opinion that claim 20 is obvious over Kleiven combined with Puchalski.

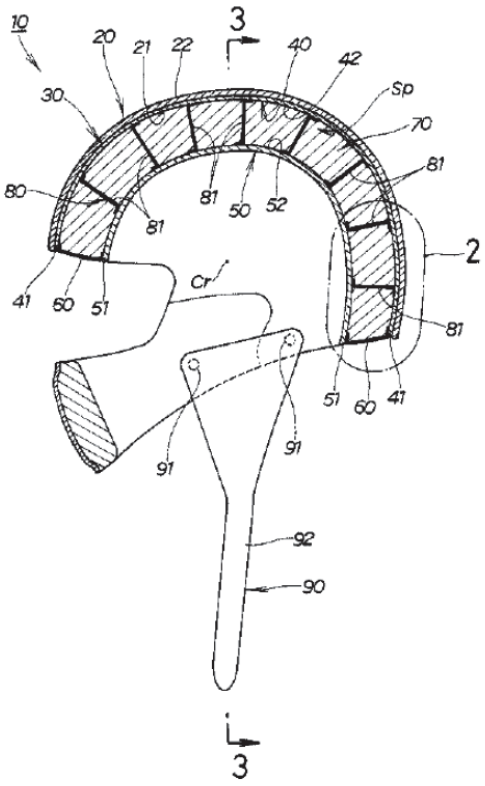
D. Ground 4: Dotsuko Anticipates Claims 1-3, 9-11, and 17-19

291. In my opinion, for the reasons discussed below in Ground 4, Dotsuko discloses each of claims 1-3, 9-11, and 17-19 arranged as in each claim.

1. Claim 1

a) 1[preamble]: "A helmet comprising:"

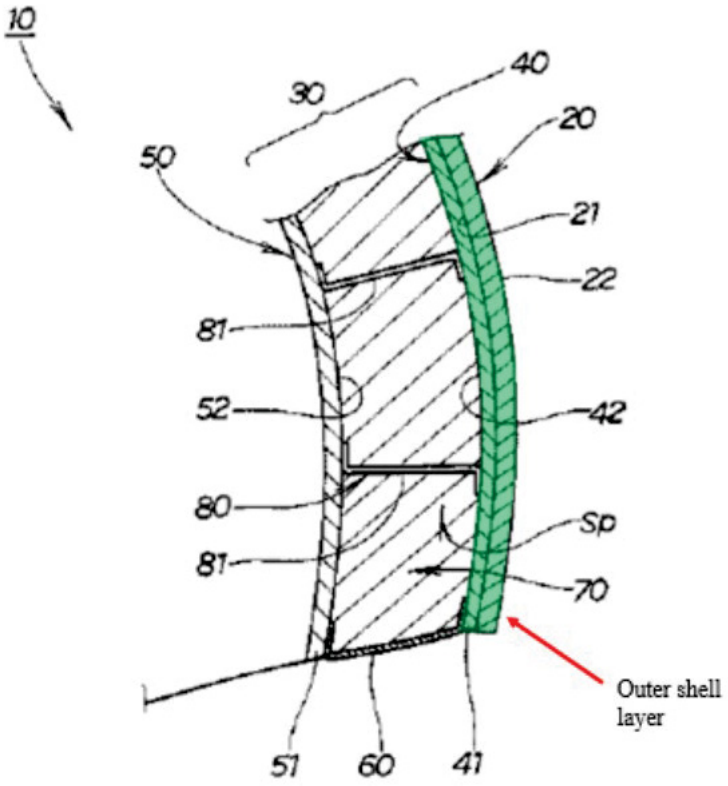
292. Dotsuko discloses a "helmet." For example, it discloses: "A helmet 10 comprises an outer shell 20, a liner 30 rotatably provided relative to the shell on the inner side thereof, a chin strap 90 provided on the liner, and a stopper mechanism 80 provided between the shell and the liner to restrict the range of relative rotation their between." Ex.1041[Dotsuko], [Abstract]. Dotsuko depicts a helmet in Figure 1 which I reproduce below.



Ex.1041[Dotsuko], Fig. 1.

b) 1[a]: "an outer shell layer;"

293. Dotsuko discloses "an outer shell layer." Dotsuko states that "helmet 10 comprises an **outermost shell 20**…." Ex.1041[Dotsuko], [0012]. I reproduce Figure 2 of Dotsuko which I annotated to show the **outer shell layer**.



Ex.1041[Dotsuko], Fig. 2.

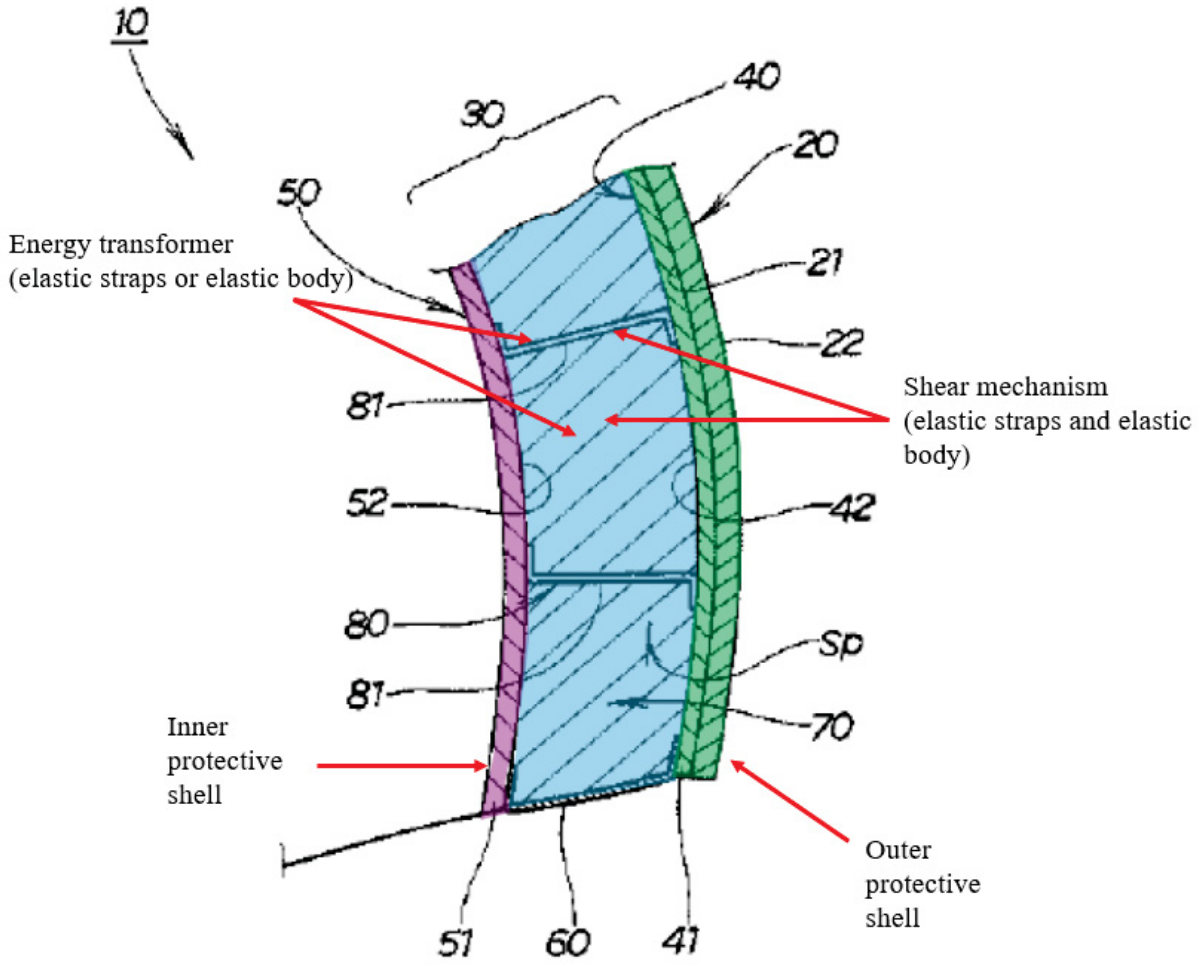
294. Dotsuko explains that its outermost shell 20 is "made of a resin molded product such as FRP (fiber-reinforce plastic)," and "[t]he outer liner 40 [is a] resin product[] made of, for example, a hard resin or a soft resin." Ex.1041[Dotsuko], [0012], [0014]. Dotsuko's outer liner made from hard resins and outer shell made from FRP are an "outer shell layer." *See also* my discussion in Section X.A.2.b) with respect to Ground 1.

c) 1[b]: "an inner shell layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the

shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

295. Dotsuko discloses "an inner shell layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material."

296. As I show below in annotated Figure 2, Dotsuko discloses a helmet in which the **inner liner 50 (inner shell layer)** is connected to **liner 40 and outer shell 20 (outer shell layer)** through the shear mechanism, *i.e.*, the elastic straps and the elastic body residing within the **layer of space Sp**, which is between the **inner liner 50 (inner shell layer)** and the **liner 40 and outer shell 20 (outer shell layer)**. Ex.1041[Dotsuko], [0013], [0017].



Ex.1041[Dotsuko], Fig. 2. Dotsuko discloses that its **inner liner 50 (inner shell layer)** is made from hard resins, and thus is an "inner shell layer." Ex.1041[Dotsuko], [0012], [0014]. *See also* my discussion in Section X.A.2.b) with respect to why Weber's outer liner is a shell layer, which also applies to Dotsuko's inner liner.

297. Dotsuko discloses a shear mechanism that includes "multiple elastic straps" and "an elastic body that is filled in the internal space" between the elastic

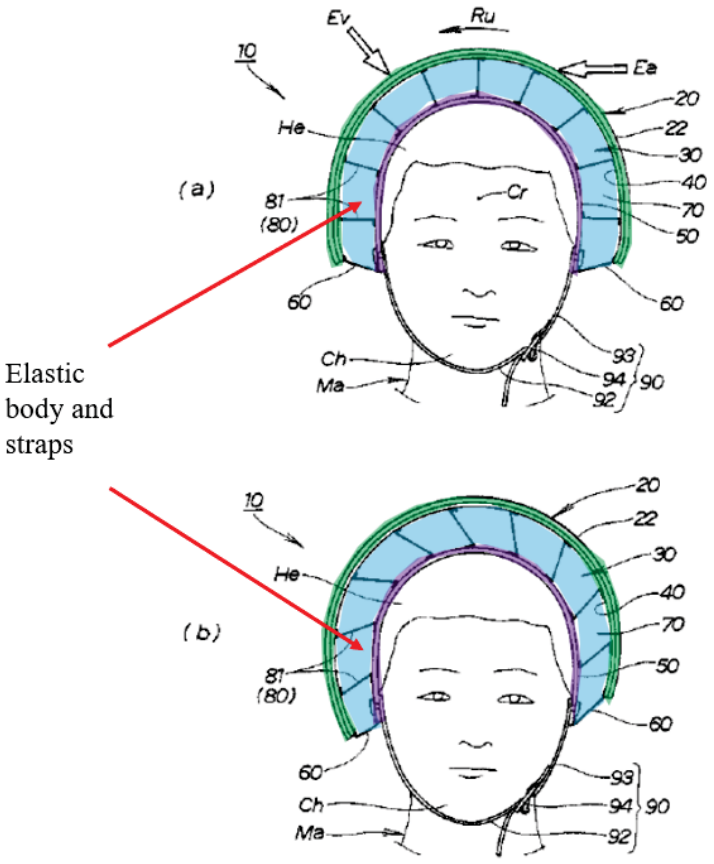
straps and thus also between the **inner liner 50 (inner shell layer)** and the **outer shell 20 (outer shell layer)**. These components are also a "**first energy transformer**" that is associated with the shear mechanism (i.e., the elastic straps and the elastic body). Dotsuko explains: "The elastic body 70 is a material that can deform" and "is composed of, for example, resin powder, a grease-like substance, or a gel-like substance." Ex.1041[Dotsuko], [0013], [0017], [0025]; *see also* Ex.1001[USP635], 6:43-45 (the '635 Patent itself explains that gels are an "absorptive/dissipative material").

298. Dotsuko's shear mechanism allows the **outer shell layer** to slide relative to the **inner shell layer**, thus absorbing impact energy. Dotsuko explains:

> **[T]he elastic body 70 displaces in the direction of the force (arrow Ru direction)** in accordance with the magnitude of the impact energy Ea. Accordingly, the **shell 20 relatively rotates with respect to the liner 30** about the rotation center Cr in the direction of the force (see Fig. 4(b)). As a result, the impact energy Ea can be efficiently and **sufficiently absorbed**.

Ex.1041[Dotsuko], [0022], Fig. 4b. This sliding is shown in Figure 4 of Dotsuko which I reproduce below.

[Fig. 4]



Ex.1041[Dotsuko], Fig. 4. Further, Dotsuko's elastic straps are a "stopper mechanism" that connects[16] the outer liner and inner liner and allows "relative rotation" between the outer shell/liner and inner liner. Dotsuko states:

> The stopper mechanism 80 restricts the shell 20 from excessively rotating relative to the liner 30 and, for

[16] discussed in Ground 1 with respect to Weber, connection per the '635 Patent may be indirect. *See* my discussion at Section X.A.2.c).

> example, is configured such that **multiple straps 81[] … connect the** inner circumferential surface 42 of **the outer liner 40 and the** outer circumferential surface 52 of the **inner liner 50**. These multiple straps 81[] … are arranged at substantially regular intervals across the entire surface between the inner circumferential surface 42 of the outer liner 40 and the outer circumferential surface 52 of the inner liner 50 and are **made of an elastic material such as rubber**. As these straps 81[] … have certain elongation properties, they **allow a certain degree of relative rotation of the shell 20 and the outer liner 40 with respect to the inner liner 50**, while preventing excessive relative rotation beyond this range.

Ex.1041[Dotsuko], [0017]. Thus, Dotsuko's elastic body and straps are shear mechanisms that shears/deforms and allow relative sliding as Figure 4 shows.

299. Dotsuko's shear mechanism includes elastic body and the elastic straps, each of which functions as a first energy transformer made of material that can absorb/dissipate and transform rotational energy, *e.g.*, by allowing for relative sliding in the same way as described in the '635 Patent. Ex.1041[Dotsuko], [0020] ("[S]hell 20 is displaced inward, enabling efficient and sufficient absorption of the impact energy Ev."); *id.*, [0021-23]; Ex.1001[USP635], 6:18-45. The straps, made from absorptive/dissipative materials such as elastic rubber, absorb energy through mechanical deformation due to their elongation properties. Ex.1041[Dotsuko], [0017]. Additionally, Dotsuko's elastic body contains a gel-like substance that "can deform within the filled internal space Sp," allowing it to absorb/dissipate energy

through both deformation and fluid flow. Ex.1041[Dotsuko], [0016]. Such gels are also identified as absorptive/dissipative materials in the '635 Patent. Ex.1001[USP635], 6:43-45; Ex.1041[Dotsuko], [0016], [0017], [0025].

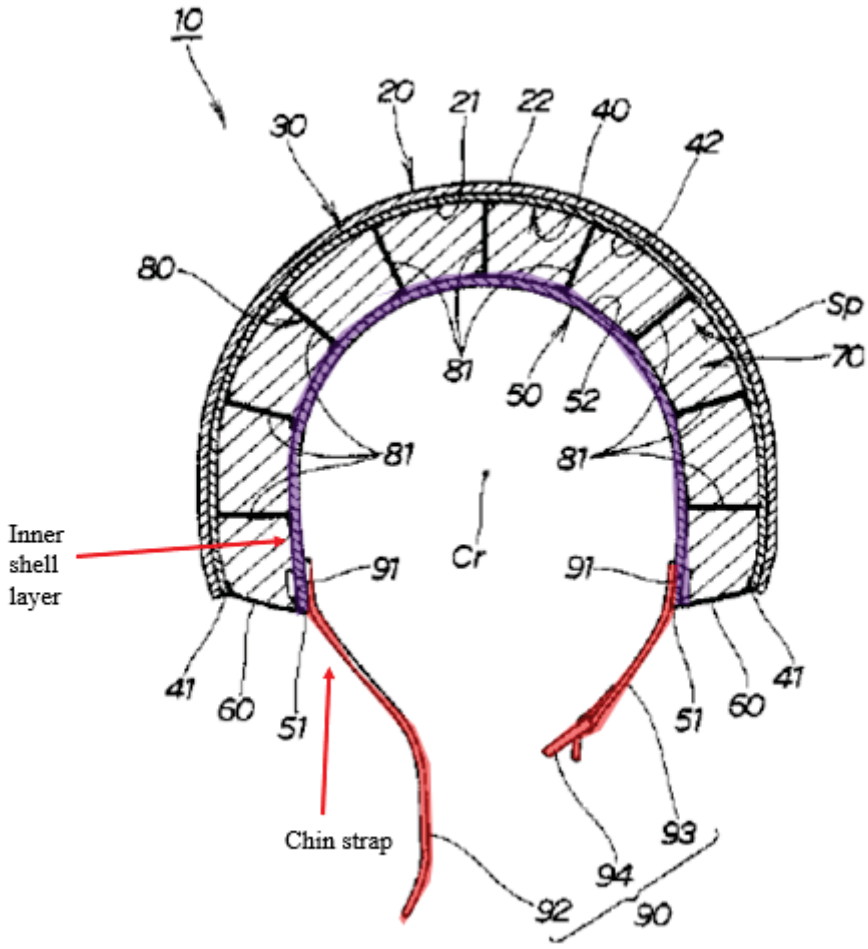
d) 1[c]: "the inner shell layer configured to conform to a human head;"

300. Dotsuko teaches "the inner shell layer configured to conform to a human head…." Dotsuko discloses that its helmet is for individuals using "motorcycles and racing cars." Ex.1041[Dotsuko], [0001]. As discussed in Section X.D.1.c), Dotsuko discloses a helmet with inner liner 50 (inner shell layer). Section X.D.1.c). Dotsuko's inner liner 50 is configured to conform to a human head because it has an "overall shape" such that it can "cover part or all of the head of the occupant (wearer) when fitted onto the head." Ex.1041[Dotsuko], [0014].

e) 1[d]: "a chin strap attached to the inner shell layer to maintain the position of the inner shell layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

301. Dotsuko teaches "a chin strap attached to the inner shell layer to maintain the position of the inner shell layer on the human head during rotational force impact while the outer shell layer is allowed to slide." Dotsuko discloses **chin-strap 90** "attached to the lower portions on the left and right sides of the **inner liner**

50…." Ex.1041[Dotsuko], [0018]. I show below an annotated Figure 3 of Dotsuko which shows the position of the chin-strap relative to the inner liner 50.



Ex.1041[Dotsuko], Fig. 3.

Dotsuko explains: "[S]ince the chin strap 90 is attached to the liner 30[17], it becomes easier for the **shell 20** to rotate relative to the liner 30 (that is, the **inner liner 50**), which is fixed to the head [] by the **chin-strap 90**. When impact energy Ea acts on the shell 20, the liner 30 (i.e., the **inner liner 50**) remains in place while the **shell 20** alone relatively rotates in the direction of the force, thereby absorbing the impact energy Ea." Ex.1041[Dotsuko], [0022].

302. Therefore, it is my opinion that Dotsuko anticipates claim 1.

2. Claim 2

a) "The helmet of claim 1, wherein the shear mechanism is a shear layer."

303. Dotsuko discloses all elements of claim 1. Section X.D. Dotsuko further discloses "the shear mechanism is a shear layer." In Dotsuko, the shear layer includes a layer of elastic straps and elastic body. Ex.1041[Dotsuko], Figs. 1, 3, and 4. *See also* Section X.D.1.c).

304. Therefore, it is Dotsuko anticipates claim 2.

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[17] Dotsuko discloses that "liner 30 comprises . . . an inner liner 50…." Ex.1041[Dotsuko], [0013]; *see also* Figure 2 in Section X.D.1.c). Therefore, inner liner 50 is included within liner 30. Further, as shown in Figure 3 of Dotsuko, the chin-strap is attached to inner liner 50.

3. Claim 3

a) "The helmet of claim 2, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer."

305. Dotsuko discloses all elements of claim 2. Section X.D.2. As discussed in Sections X.D.1.c) and X.D.2, Dotsuko's shear layer, comprising elastic straps and an elastic body, individually and/or in the aggregate connects the outer and inner shell layers, incorporating first absorptive/dissipative materials (e.g., elastic/rubber) to facilitate relative sliding between them. Sections X.D.1.c) and X.D.2. The first energy transformer (elastic body or elastic straps) absorbs energy from forces imparted onto the outer shell layer and connects the shear layer to the outer shell layer. *See* Section X.D.1.c).

306. Therefore, Dotsuko anticipates claim 3.

4. Claim 9

a) 9[preamble]: "Protective gear comprising:"

307. In my opinion, Dotsuko discloses "[p]rotective gear" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.D.1.a).

b) 9[a]: "an outer shell layer;"

308. In my opinion, Dotsuko discloses "an outer shell layer" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.D.1.b).

c) 9[b]: "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

309. In my opinion, Dotsuko discloses "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.D.1.c). I note that the "inner conforming layer" in claim 9 is encompassed within the "inner shell layer" in claim 1. Specifically, claim 1 describes that its "inner shell layer" is "configured to conform to a human head," making the inner shell layer also an "inner conforming layer." Consistent with this understanding, claim 9 similarly states its "inner conforming layer" is "configured to conform to a human head." The '635 Patent's specification does not describe "conforming layer" or "conform" anywhere except the claims, and it does not provide any other discussion that would alter my understanding. To the extent there is any difference between "inner shell

layer" and "inner conforming layer", in my view, both inner shell layer and inner conforming layer are taught by Dotsuko.

d) 9[c] "the inner conforming layer configured to conform to a human head;"

310. In my opinion, Dotsuko discloses "the inner conforming layer configured to conform to a human head" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.D.1.d).

e) 9[d]: "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

311. In my opinion, Dotsuko discloses "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.D.1.e).

312. For all of the reasons discussed above, it is my view that Dotsuko anticipates claim 9.

5. Claim 10

a) "The protective gear of claim 9, wherein the shear mechanism is a shear layer."

313. Dotsuko discloses all elements of claim 9. Section X.C.7. In my opinion, Dotsuko discloses "the shear mechanism is a shear layer." Specifically, Dotsuko discloses claim 10 for the same reasons as I discussed above with respect to claim 2. *See* my discussion in Section X.D.2 above, which I incorporate here.

314. Therefore, in my view, Dotsuko anticipates claim 10.

6. Claim 11

a) "The protective gear of claim 10, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer."

315. Dotsuko discloses all elements of claim 10. Section X.C.8. In my opinion, Dotsuko discloses "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer." Specifically, Dotsuko discloses claim 11 for the same reasons as I discussed above with respect to claim 3. *See* my discussion in Section X.D.3 above, which I incorporate here.

316. Therefore, in my view, Dotsuko anticipates claim 11.

7. Claim 17

a) 17[preamble]: "A helmet comprising:"

317. In my opinion, Dotsuko discloses "[a] helmet" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.D.1.a) and X.C.13.a).

b) 17[a]: "an outer shell layer;"

318. In my opinion, Dotsuko discloses "an outer shell layer" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.D.1.b) and X.C.13.b).

c) 17[b]: "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

319. In my opinion, Dotsuko discloses "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.D.1.c) and X.D.4.c).

d) 17[c] "the inner conforming layer configured to conform to a human head;"

320. In my opinion, Dotsuko discloses "the inner conforming layer configured to conform to a human head" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.D.1.d) and X.D.4.d).

e) 17[d]: "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

321. In my opinion, Dotsuko discloses "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.D.1.e) and X.D.4.e).

322. For all of the reasons discussed above, Dotsuko anticipates claim 17.

8. Claim 18

a) "The helmet of claim 17, wherein the shear mechanism is a shear layer."

323. Dotsuko discloses all elements of claim 17. Section X.C.8. In my opinion, Dotsuko discloses "the shear mechanism is a shear layer." Specifically, Dotsuko discloses claim 18 for the same reasons as I discussed above with respect to claims 2 and 10. *See* my discussion in Sections X.D.2 and X.D.5 above, which I incorporate here.

324. Therefore, in my view, Dotsuko anticipates claim 18.

9. Claim 19

a) "The helmet of claim 18, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer."

325. Dotsuko discloses all elements of claim 18. Section X.C.14. In my opinion, Dotsuko discloses "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer." Specifically, Dotsuko discloses claim 19 for the same reasons as claims 3 and 11. *See* my discussion in Section X.D.3 and X.D.6.

326. Therefore, it is my view that Dotsuko anticipates claim 19.

E. Ground 5: Claims 8 and 16 are Obvious over Dotsuko Combined With Puchalski

1. Claim 8

a) "The helmet of claim 1, wherein a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head."

327. As I discussed above in Section X.D, Dotsuko discloses all elements of claim 1. *See* my discussion above in Section X.D. Dotsuko combined with Puchalski teaches "a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head." Puchalski describes "[a] helmet…includ[ing] a shell contoured to the shape of the user's head, with cushioning along at least part of the shell interior and a chinstrap." Ex.1011[Puchalski], Abstract; *id.*, cl. 9 ("The helmet of claim 1 further including impact absorbing cushioning secured to an inner surface of said shell, said cushioning being resiliently compressible so as to compress with any movement of said first portion relative to said second portion."). Additionally, Puchalski teaches that "padding or cushioning [(i.e., "a lining layer")] may also be provided along the inside of the shell for increased comfort, better fit and to assist in the absorption of any impact forces." Ex.1011[Puchalski], 1:52-55. Puchalski's padding or cushioning is "a lining layer" that is connected to the inner surface of the inner shell/ layer and is located between the inner shell/layer and the wearer's head.

328. It is my opinion that a POSA would have been motivated to combine Dotsuko's helmet with Puchalski's lining layer and would have had a reasonable expectation of success in doing so. Dotsuko and Puchalski are analogous art to the challenged claims because they are in the same/similar field of helmet design and

directed to the same problem of rotational impact/force and injury. They also arrive at a similar solution: improving helmet safety by using helmets with layers that slide relative to each other. Dotsuko discloses that its helmet is for individuals using "motorcycles and racing cars." Ex.1041[Dotsuko], [0001]. By 2011, it was standard in the field to use comfort padding (lining layer) in motorcycle helmets. Ex.1031[Bosch], 17. Puchalski discloses that its helmets too are intended for "motorcycle or race car driver[s]," and its "strips of resiliently compressible foam cushioning" "assist[] in maintaining the shell [] comfortably in the correct position on top of the user's head [] and furthermore, advantageously acts to assist in the absorption of impact forces." Ex.1011[Puchalski], 7:34-39, 13:48-58; *see also id.*, 1:52-55. In my opinion, a POSA would have therefore been motivated to use Dotsuko's helmet with Puchalski's lining layer incorporated to achieve increased comfort and additional impact-force absorption. It is also my opinion that a POSA would have found it obvious to combine these elements as a matter of routine implementation, as it is a straightforward and predictable combination of known elements according to known methods to yield predictable results, and Dotsuko's helmet is ready for improvement through incorporation of Puchalski's lining layer. This known technique of adding a comfort liner to a helmet would improve

Dotsuko's helmet in a similar way that Puchalski's helmet was improved with this liner.

329. Additionally, a POSA would have reasonably expected success using Puchalski's comfort liner in Dotsuko's helmet design. It was well known and standard practice for helmets, including motorcycle helmets, to have comfort padding. Ex.1031[Bosch], 2; Ex.1011[Puchalski], Abstract, 13:48-58; *see also* my discussion in Section VI. A POSA would have, as a matter of routine implementation, been able to configure Puchalski's comfort liner to fit Dotsuko's design, including because Puchalski's comfort liner is positioned under an inner shell layer similar to Dotsuko's and would easily fit into Dotsuko's design.

330. Therefore, in my view, Dotsuko combined with Puchalski renders claim 8 obvious.

2. Claim 16

a) "The protective gear of claim 9, wherein the inner conforming layer is associated with a lining material configured to conform to a human head."

331. As I discussed above in Section X.D.4, Dotsuko discloses all elements of claim 9. *See* my discussion above in Section X.D.4. In my opinion, Dotsuko combined with Puchalski discloses "the inner conforming layer is associated with a lining material configured to conform to a human head." Specifically, Dotsuko

combined with Puchalski discloses claim 16 for the same reasons as I discussed above with respect to claim 8. *See* my discussion in Section X.E.1 above, which I incorporate here.

332. Therefore, in my view, claim 16 is obvious over Dotsuko combined with Puchalski.

F. Ground 6: Madey Anticipates Claims 1-3, 8-11, and 16-19.

333. In my opinion, for the reasons discussed below in Ground 6, Madey discloses each of claims 1-3, 8-11, and 16-19 arranged as in each claim.

1. Claim 1

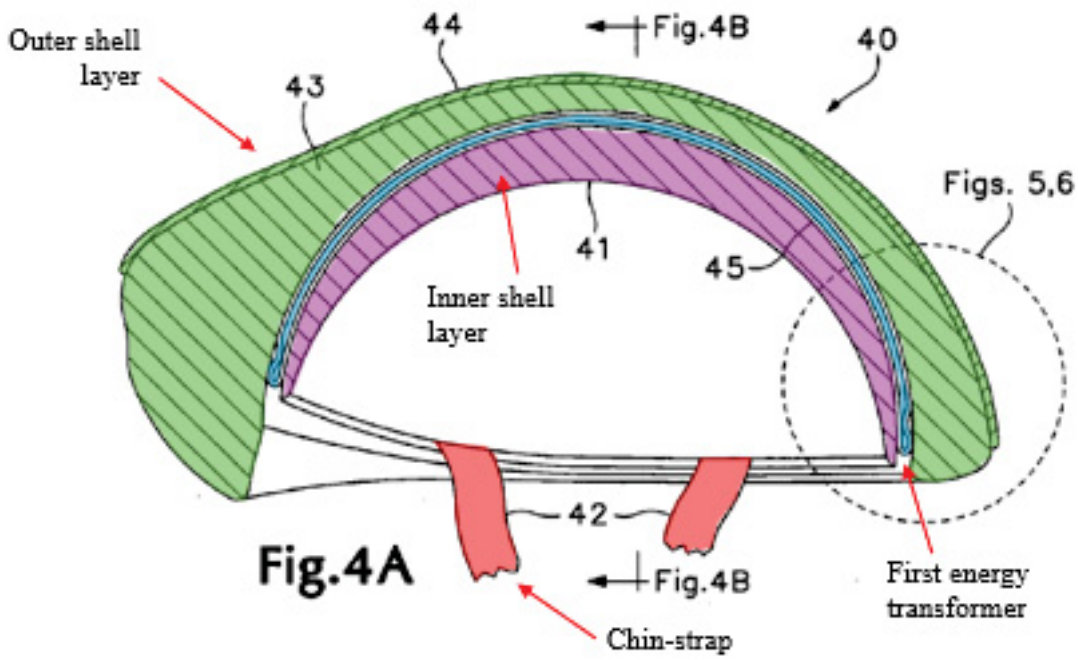
a) 1[preamble]: "A helmet comprising:"

334. Madey discloses a "helmet." For example, it discloses: "[a] helmet comprising: an inner helmet layer; an outer helmet layer; and an interface layer disposed between the inner and outer helmet layers, the interface layer allowing displacement of the outer helmet layer with respect to the inner helmet layer in response to a tangential impact force applied to the outer helmet layer." Ex.1047[Madey], claim 1, Fig. 4A.

b) 1[a]: "an outer shell layer;"

335. Madey discloses "an outer shell layer." Madey discloses that "[h]elmet 40 comprises…an **outer helmet layer** (the combination of energy-absorbing layer

43 and microshell 44 in this embodiment)…." Ex.1047[Madey], [0025]. I reproduce Figure 4B of Madey which I annotated to show the outer shell layer.



Ex.1047[Madey], Fig. 4A.

336. Madey explains that its outer helmet layer comprises "a hard shell." Ex.1047[Madey], claim 2. Madey provides potential materials that the outer shell may be made of: "titanium/titanium alloys; epoxies; fiberglass-epoxy composites; carbon-fiber-epoxy composites; polyethylene; polycarbonate; and fluoropolymers." Ex.1047[Madey], [0050].

c) 1[b]: "an inner shell layer connected to the outer shell layer through a shear mechanism allowing the outer shell

layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

337. Madey discloses "an inner shell layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material." As I show below in an annotated Figure 9B of Madey, Madey discloses a helmet in which the **inner helmet layer 92** (inner shell layer) connects to **outer helmet layer 90** (outer shell layer) through an **interface layer 94** that contains hyper-elastic columns 96. Ex.1047[Madey], [0037], Fig. 9B. Madey also discloses that an interface layer 45 is disposed between the outer and inner helmet layers. Ex.1047[Madey], [0025]. Madey's "inner helmet layer" made of, for example, expanded polystyrene foam, is an inner shell layer. Ex.1047[Madey], Abstract, [0025], [0037], [0050], Claim 1, Fig. 4. *See also* my discussion in Section X.A.2.b) with respect to Ground 1. The shear mechanism is the components between Madey's **outer helmet layer 90** and **inner helmet layer 92** that shear and "allow[] the outer helmet layer to displace with respect to the inner helmet layer, thereby absorbing and/or diverting forces", specifically **hyper-elastic columns 96** (shear mechanism). Ex.1047[Madey], Abstract, [0037]. The **inner helmet layer 92** is connected to the **outer helmet layer 90** through **hyper-elastic**

columns 96 (shear mechanism) and allow **outer helmet layer 90** to slide relative to **inner helmet layer 92**. As I discussed in Ground 1 with respect to Weber, connection per the '635 Patent may be indirect. *See* my discussion at Section X.A.2.c). The shear mechanism includes a first energy transformer, which is the **hyper-elastic columns 96** in **interface layer 94** because the columns transform energy. Madey discloses that "columns 96 buckle under an impact force to **absorb impact energy**". Ex.1047[Madey], [0037]. The hyper-elastic columns transform energy from impact forces on the outer layer of the helmet to other types of energy through sliding.

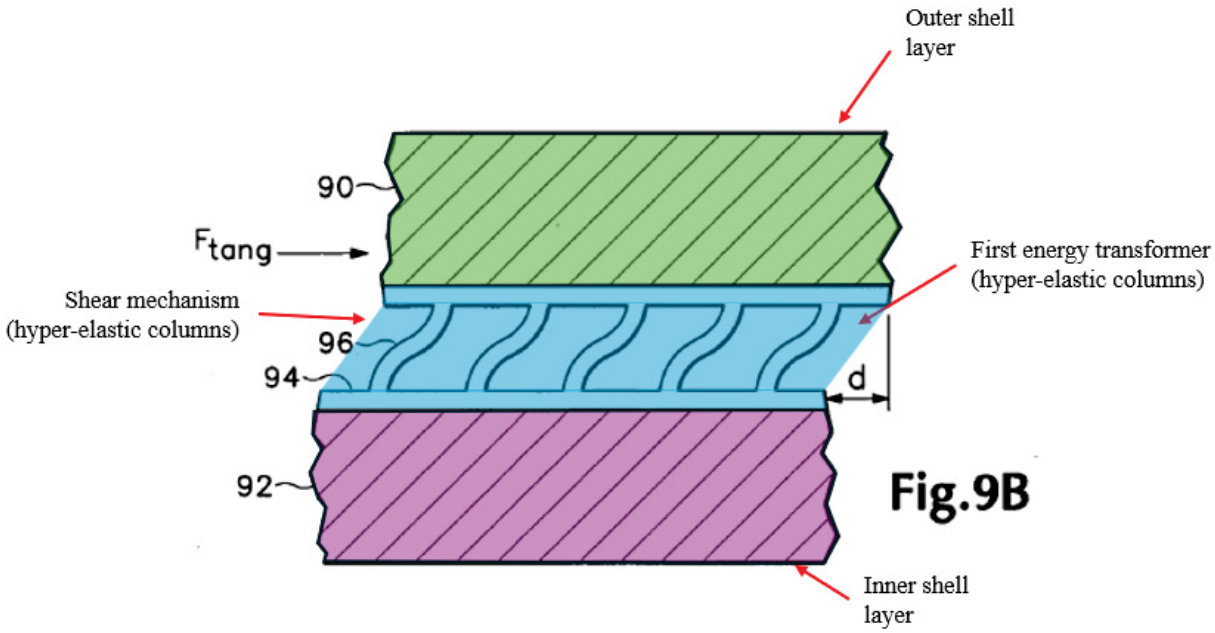


Fig.9B

Ex.1047[Madey], Fig. 9B.

338. Madey also discloses that **interface layer 94** shears and allows the **outer shell layer** (**outer helmet layer 90**) of Madey to slide relative to the **inner shell layer** (**inner helmet layer 92**). Madey discloses that its **hyper-elastic columns 96**, part of the **interface layer 94**, "bend and stretch in response to tangential force" and thereby allow "a relative displacement" between the outer and inner helmet layers. Ex.1047[Madey], [0037].

339. Madey explains that the shear mechanism allows the **outer shell layer** to slide relative to the **inner shell layer**. Madey explains:

> Columns 96 buckle under an impact force to **absorb impact energy**. And as shown in FIG. 9B, application of a force F_{tang} to **one of the helmet layers results in a relative displacement d** as columns 96 bend and stretch in response to the tangential force, thereby **deflecting** and partially **absorbing the tangential force**.

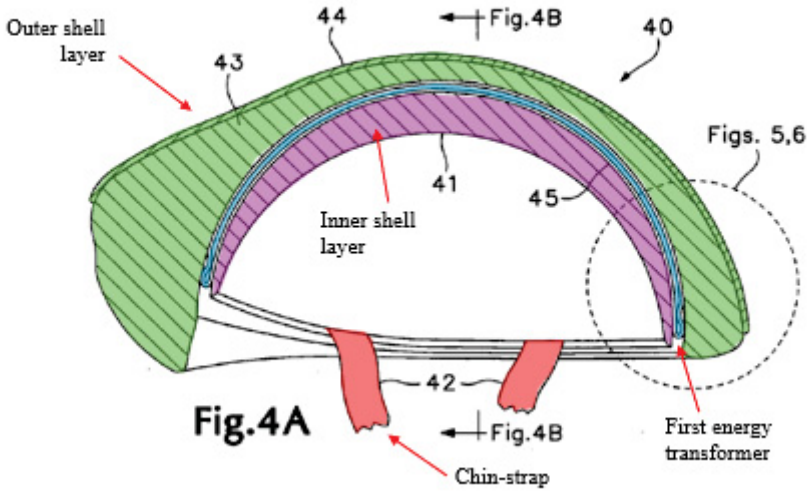
Ex.1047[Madey], [0037]. Thus, Madey discloses the outer shell layer sliding relative to the inner shell layer. Madey discloses to those of ordinary skill in the art lateral/rotational movement of the layers in Madey's helmet, enabled by hyper-elastic columns 96, constitutes relative sliding, as required by the claim, in a manner similar to, if not the same as, that described in Fig. 5 of the '635 Patent. Therefore,

Madey's hyper-elastic columns permit translational movement, which in turn dissipates energy by deflecting it.

340. Further, Madey's hyper-elastic columns 96 (first energy transformer) that are part of interface layer 94 (shear mechanism) are composed of an absorptive/dissipative material. Madey's hyper-elastic columns 96 are composed of an elastic material that allows them to "bend and stretch in response to the tangential force, thereby deflecting and partially absorbing the tangential force." Ex.1047[Madey], [0037]. Madey's hyper-elastic columns are also composed of absorptive/dissipative materials because they allow for relative sliding between the outer shell layer and the inner shell layer.

d) 1[c] "the inner shell layer configured to conform to a human head;"

341. Madey teaches "the inner shell layer configured to conform to a human head." Madey's helmets include "a helmet retention system (e.g., straps 42 and foam padding inserts, not shown) to affix inner helmet layer 41 to a wearer's head…." Ex.1047[Madey], [0025], Fig. 4A. Additionally, as shown in Fig. 4A, Madey's inner shell layer is contoured to fit a human head.

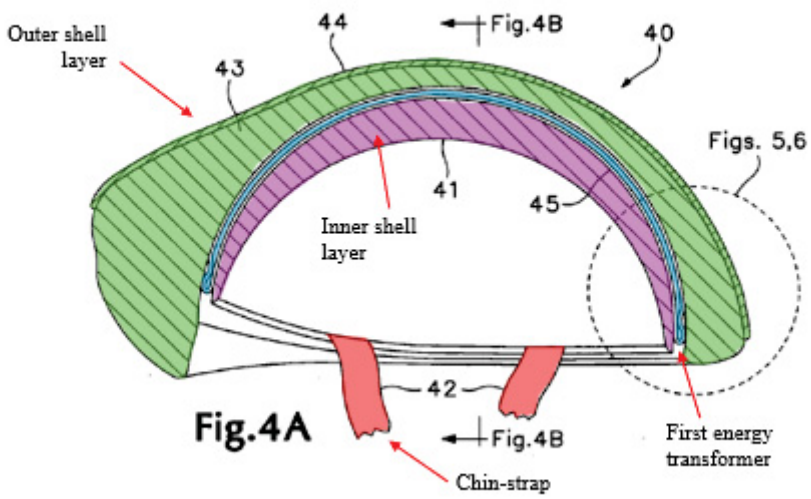


Ex.1047[Madey], Fig. 4A.

e) 1[d]: "a chin strap attached to the inner shell layer to maintain the position of the inner shell layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

342. Madey teaches "a chin strap attached to the inner shell layer to maintain the position of the inner shell layer on the human head during rotational force impact while the outer shell layer is allowed to slide." As Section X.F.1.d) discusses, Madey's helmet includes a helmet retention system. In addition to foam padding inserts, Madey also teaches that the retention system incorporates **straps 42** to affix the inner shell layer to the wearer's head. Ex.1047[Madey], [0025] ("[A] helmet retention system (e.g., **straps 42** and foam padding inserts, not shown) to affix **inner helmet layer 41** to a wearer's head…."), Fig. 4A. Madey explains that a helmet

retention system "allows the user to attach the helmet securely to the head, usually with a **chinstrap** and increasingly with a suspended rear strap or member that aligns the helmet properly on the wearer's head." Ex.1047[Madey], [0005]. To a POSA chinstrap 42 in Figure 4 of Madey is attached to inner shell layer.



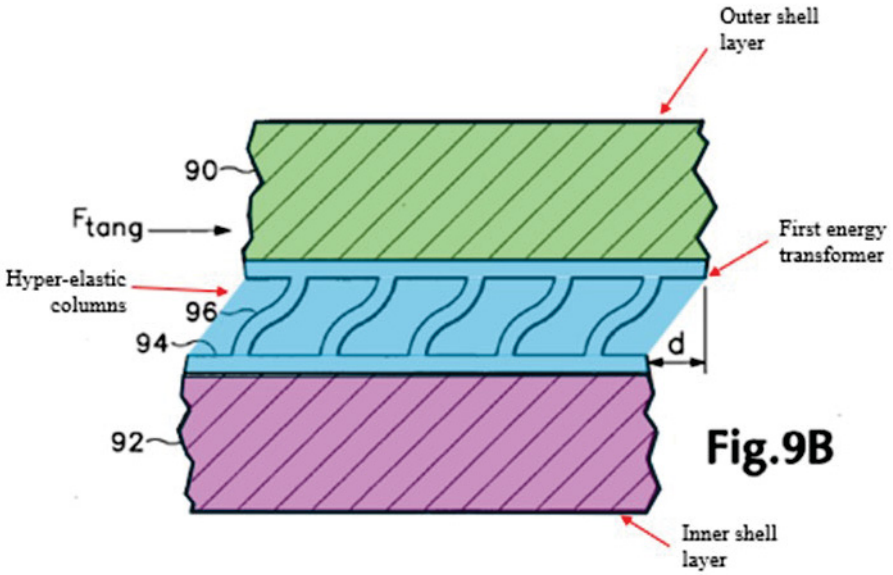
Ex.1047[Madey], Fig. 4A. Madey's chinstrap 42 is affixed to the "inner helmet layer" and secures it to the head during relative displacement (sliding) of the outer layer. Ex.1047[Madey], [0037], Fig. 9B.

343. Therefore, it is my opinion that Madey anticipates claim 1.

2. Claim 2

a) "The helmet of claim 1, wherein the shear mechanism is a shear layer."

344. As I discussed above in Section X.F.1 and incorporate here, Madey discloses all elements of claim 1. See my discussion above in Section X.F.1. Madey further discloses that "the shear mechanism is a shear layer." Madey's "interface layer 94" (which includes hyper-elastic columns 96) is a "layer." Ex.1047[Madey], [0037] ("Interface layer 94 comprises a lamellar structure of hyper-elastic columns 96"), Fig. 9B; *see also* my discussion in Section X.F.1.c) with respect to claim 1. For example, Figure 9B of Madey which I reproduce below shows how hyper-elastic columns 96 are arranged as interface "layer" 94.



Ex.1047[Madey], Fig. 9B.

345. Therefore, it is my opinion that Madey anticipates claim 2.

3. Claim 3

a) "The helmet of claim 2, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer."

346. As I discussed above in Section X.F.2 and incorporate here, Madey discloses all elements of claim 2. *See* my discussion above in Section X.F.2. Madey further discloses that "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer." As I described in Sections X.F.1.c) and X.F.2, Madey's interface layer (shear layer) includes hyper elastic columns (first energy transformer) that connect the interface layer to the outer helmet shell and are made of absorptive/dissipative materials (elastic). These hyper-elastic columns absorb energy from forces imparted onto the outer shell layer and allow the outer shell layer to slide relative to the inner shell layer. *See* Sections X.F.1.c) and X.F.2.

347. Therefore, it is my opinion that Madey anticipates claim 3.

4. Claim 8

a) "The helmet of claim 1, wherein a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head."

348. As I discussed above in Section X.F.1 and incorporate here, Madey discloses all elements of claim 1. *See* my discussion above in Section X.F.1. Madey discloses "a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head." Madey teaches that the inner helmet layer is held in place on the wearer's head (and thus conformed to the wearer's head) by a retention system, which consists of foam padding inserts. Ex.1047[Madey], [0025] ("[A] helmet retention system (e.g., straps 42 and **foam padding inserts**, not shown) to affix inner helmet layer 41 to a wearer's head…."). Additionally, Madey teaches that the innermost layer of the helmet can provide "head cushioning" as part of the helmet retention system. Ex.1047[Madey], [0051]. The foam padding insert in Madey is a lining layer that is affixed to the inner surface of the inner shell layer. Thus, Madey's helmet retention system or cushioning is "a lining layer" that is connected to the inner surface of the inner shell layer and is located between the inner shell layer and the wearer's head.

349. Therefore, it is my opinion that Madey anticipates claim 8.

5. Claim 9

a) 9[preamble]: "Protective gear comprising:"

350. Madey discloses "protective gear." Madey discloses "head protective devices." Ex.1047[Madey], Title, [0002] (discussing a helmet), [0037] (discussing the helmet with an alternative interface layer), claim 1, Fig. 4. The '635 Patent specifies "helmets" are "protective gear." Ex.1001[USP635], 1:30.

b) 9[a]: "an outer shell layer;"

351. In my opinion, Madey discloses "an outer shell layer" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.F.1.b).

c) 9[b]: "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

352. In my opinion, Madey discloses "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.F.1.c). I note that the "inner conforming layer" in claim 9 is encompassed within the "inner shell layer" in claim 1. Specifically, claim 1 describes that its "inner shell layer" is "configured to conform to a human head," making the inner shell layer also

an "inner conforming layer." Consistent with this understanding, claim 9 similarly states its "inner conforming layer" is "configured to conform to a human head." The '635 Patent's specification does not describe "conforming layer" or "conform" anywhere except the claims, and it does not provide any other discussion that would alter my understanding. To the extent there is any difference between "inner shell layer" and "inner conforming layer", in my view, both inner shell layer and inner conforming layer are taught by Madey. *See* Section X.F.1.c).

d) 9[c] "the inner conforming layer configured to conform to a human head;"

353. In my opinion, Madey discloses "the inner conforming layer configured to conform to a human head" for the same reasons as I discuss above with respect to claim 1. See my discussion in Section X.F.1.d).

e) 9[d]: "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

354. In my opinion, Madey discloses "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide" for the same reasons as I discuss above with respect to claim 1. See my discussion in X.F.1.e).

355. Therefore, it is my opinion that Madey anticipates claim 9.

6. Claim 10

a) "The protective gear of claim 9, wherein the shear mechanism is a shear layer."

356. Madey discloses all elements of claim 9. Section X.F.5. In my opinion, Madey discloses "the shear mechanism is a shear layer." Specifically, Madey discloses claim 10 for the same reasons as I discussed above with respect to claim 2. *See my* discussion in Section X.F.2 above, which I incorporate here.

357. Therefore, it is my opinion that Madey anticipates claim 10.

7. Claim 11

a) "The protective gear of claim 10, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer."

358. Madey discloses all elements of claim 10. Section X.F.6. In my opinion, Madey teaches "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer." Specifically, Madey discloses claim 11 for

the same reasons as I discussed above with respect to claim 3. *See* my discussion in Section X.F.3 above, which I incorporate here.

359. Therefore, it is my opinion that Madey anticipates claim 11.

8. Claim 16

a) "The protective gear of claim 9, wherein the inner conforming layer is associated with a lining material configured to conform to a human head."

360. As I discussed above in Section X.F.5, Madey discloses all elements of claim 9. *See* my discussion above in Section X.F.5. In my opinion, Madey discloses "the inner conforming layer is associated with a lining material configured to conform to a human head." Specifically, Madey discloses claim 16 for the same reasons as I discussed above with respect to claim 8. *See my* discussion in Section X.F.4 above, which I incorporate here.

361. Therefore, it is my opinion that Madey anticipates claim 16.

9. Claim 17

a) 17[preamble]: "A helmet comprising:"

362. In my opinion, Madey discloses "[a] helmet" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.F.1.a) and X.F.5.a).

b) 17[a]: "an outer shell layer;"

363. In my opinion, Madey discloses "an outer shell layer" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.F.1.b) and X.F.5.b).

c) 17[b]: "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,"

364. In my opinion, Madey discloses "an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.F.1.c) and X.F.5.c).

d) 17[c] "the inner conforming layer configured to conform to a human head;"

365. In my opinion, Madey discloses "the inner conforming layer configured to conform to a human head" for the same reasons as I discuss above with respect to claims 1 and 9. See my discussion in Sections X.F.1.d) and X.F.5.d).

e) 17[d]: "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide."

366. In my opinion, Madey discloses "a chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide" for the same reasons as I discuss above with respect to claims 1 and 9. *See* my discussion in Sections X.F.1.e) and X.F.5.e).

367. Therefore, it is my opinion that Madey anticipates claim 17.

10. Claim 18

a) "The helmet of claim 17, wherein the shear mechanism is a shear layer."

368. Madey discloses all elements of claim 17. Section X.F.9. In my opinion, Madey discloses "the shear mechanism is a shear layer." Specifically, Madey discloses claim 18 for the same reasons as I discussed above with respect to claims 2 and 10. *See* my discussion in Sections X.F.2 and X.F.6 above, which I incorporate here.

369. Therefore, it is my opinion that Madey anticipates claim 18.

11. Claim 19

a) "The helmet of claim 18, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer."

370. Madey discloses all elements of claim 18. Section X.F.10. In my opinion, Madey discloses "the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer." As I discussed above, Madey discloses claim 19 for the same reasons as claims 3 and 11. *See* my discussion in Sections X.F.3 and Section X.F.7.

371. Therefore, it is my opinion that Madey anticipates claim 19.

XI. AVAILABILITY FOR CROSS-EXAMINATION

372. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross examination in the case and that cross examination will take place within the United States. If cross examination is required of me, I will appear for cross examination within the United States during the time allotted for cross examination.

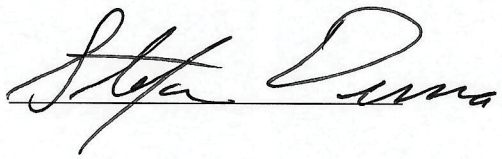
XII. RIGHT TO SUPPLEMENT

373. I reserve the right to supplement my opinions in the future to respond to any arguments that Patentee raises and to take into account new information as it becomes available to me.

XIII. JURAT

374. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: July 9, 2025



Stefan M. Duma, PhD

APPENDIX A

CURRICULUM VITAE

Stefan M. Duma

July 2, 2025

University Distinguished Professor
Harry C. Wyatt Professor of Engineering
Biomedical Engineering and Mechanics, Virginia Tech

Executive Director
Institute for Critical Technology and Applied Science, Virginia Tech

Interim Department Head
Biomedical Engineering and Mechanics, Virginia Tech

Affiliate Faculty, School of Neuroscience
Affiliate Professor, Sports Medicine, Via College of Osteopathic Medicine

Principal Engineer and Founder
Duma Engineering

Google Scholar: http://scholar.google.com/citations?user=cZhQN8YAAAAJ&hl=en

EDUCATION:

2000 Ph.D. Mechanical Engineering, University of Virginia
Dissertation: "Small Female Upper Extremity Injury Criteria"
1996 M.S. Industrial Engineering, University of Cincinnati
Thesis: "An Experimental Study of Airbag Induced Eye Injuries"
1995 B.S. Mechanical Engineering, University of Tennessee, Knoxville

PROFESSIONAL APPOINTMENTS (all at Virginia Tech unless noted)**:**

2023-present Interim Department Head, Biomedical Engineering and Mechanics
2022-present University Distinguished Professor
2018-present Executive Director, Institute of Critical Technology and Applied Science
2016-2018 Interim Executive Director, Institute of Critical Technology and Applied Science

- Responsible for developing interdisciplinary research across 300 faculty in engineering and science with over $100M annual expenditures
- Strategically invest annual $8.3M budget and oversee four buildings with over 250,000 sq.ft. of research and laboratory space
- Directly supervise organization of 45 faculty and staff and responsible for key university research initiatives in drone development, Quantum science, cyber security, and material characterization at the macro and nano levels.
- Created diversity and inclusion seed grant program for developing faculty partnerships between Virginia Tech and HBCUs or MSIs

2017-2024 Editor in Chief, Annals of Biomedical Engineering
- Flagship journal of the Biomedical Engineering Society
- Increased the Impact Factor from 3.22 to 4.22
- Manage over 1,000 manuscript submissions each year
- Recruited new Editorial Board and increased diversity by increasing female membership from 35% to 51%, and also increasing URMs from 5% to 13%

2017-present Affiliate Faculty, School of Neuroscience

2016-2021 Founding Director, Adaptive Brain and Behavior Destination Area
- Developed a new interdisciplinary course on Concussion Perspectives, and teach it to over 1,500 students each year across all colleges at Virginia Tech
- Created a new minor in Adaptive Brain and Behavior that has grown to be the 2nd most popular minor in the Pathways program

2009-present Harry C. Wyatt Professor of Engineering

2007-present Affiliate Professor, Sports Medicine, Via College of Osteopathic Medicine

2014-2016 Department Head, Biomedical Engineering and Mechanics (BEAM)
- Created the BEAM department through the merger of two departments: Biomedical Engineering, and Engineering Science and Mechanics
- Directly supervised 55 faculty and 25 staff with an annual budget of $5M
- Grew research expenditures by 37% from $8.3M to $11.3M and increased faculty actively involved in research from 55% to 74%
- Created BEM minor and initiated the full degree program in BME
- Lead a transition to hire 12 instructors and collegiate faculty to teach 2,500 engineering students fundamental mechanics courses each year

2009-2016 Director, School of Biomedical Engineering and Sciences
- Joint graduate program between Virginia Tech and Wake Forest University
- Grew faculty from 10 to 65 and increased research expenditures from $5M/year to over $45M/year across both campuses
- Increased US News ranking from #53/89 (60%) to #35/115 (30%)
- Advanced philanthropic giving by securing two estate gifts and increasing annual charitable giving to the program

2012 Interim Department Head, Mechanical Engineering
- Nine month appointment to oversee department during leadership transition

2009-2016 Founding Director of the Helmet Lab and the Virginia Tech Helmet Ratings Program
- Pioneered instrumenting football players to study concussion biomechanics
- Transformed helmet industry with creation of the helmet ratings program
- Lead research to improve safety in female sports (Lacrosse, rugby, soccer)
- Advisor to the NCAA and Pop Warner on sport rules to reduce head impacts
- Created outreach programs for K-12 student engagement

2006-2009 Associate Department Head for Research, Mechanical Engineering

2006-2009 John Jones III Fellow in Mechanical Engineering

2006-2009 Professor, Mechanical Engineering

2003-2009 Founding Director, Center for Injury Biomechanics, Virginia Tech and Wake Forest
- Recruited 10 primary faculty to develop internationally leading injury biomechanics program with 60 students and staff

- Designed and built a 20,000 sq.ft. biomechanics lab and secured funding for the project with a mix of state, federal, and private sources
- Developed federal sponsors (NIH, DOD, DOT, NSF, FAA) and industrial sponsors (Toyota, Ford, Honda, Hasbro, TRW, Autoliv)
- Lead research in pregnant occupant and female automobile safety restraints

2003-2006 Associate Professor, Mechanical Engineering
2000-2003 Assistant Professor, Mechanical Engineering
1996-2000 Graduate Research Assistant, University of Virginia
1995-1996 NIOSH Graduate Fellow, University of Cincinnati
1994 Summer Intern, Procter and Gamble, Jackson TN
1993 Summer Intern, Oak Ridge National Laboratory, Oak Ridge TN
1992 Summer Intern, United Parcel Service, Memphis TN

AWARDS AND HONORS:

2017 Fellow, Biomedical Engineering Society: *for advancing concussion research and helmet design across all sports, improved pregnant occupant safety, reduced eye and head injuries in soldiers, and designed safer light sabers.*
2016 Editor's Choice Award, Most Downloaded Article, Annals of Biomedical Engineering
2015 Fellow, American Institute for Medical and Biological Engineering: *for outstanding contributions to the safety of athletes, occupants, and consumers through research in injury biomechanics*
2014 Editor's Choice Award, Most Downloaded Article, Annals of Biomedical Engineering
2012 Editor's Choice Award of Excellent, Annals of Biomedical Engineering
2010 Fellow, Association for the Advancement of Automotive Medicine: *for foundational research and advancing automobile safety for pregnant occupants*
2008 Army Modeling and Simulation Award 2008 (1 award from 57 nominations across the US)
2007 Best Paper, 51st Association for the Advancement of Automotive Medicine Conference
2006 Outstanding Achiever Award, Association for the Advancement of Automotive Medicine
2006 Technology Review: TR35 Award for Innovation in Biomechanics Research
2005 Ralph R. Teetor Educational Award, Society of Automotive Engineers
2005 Best Paper, 49th Association for the Advancement of Automotive Medicine Conference
2005 Young Scientist Award, American Society of Biomechanics, Post-doctoral
2003 Best Paper, 47th Association for the Advancement of Automotive Medicine Conference
2002 Best Paper, 42nd Stapp Car Crash Conference
2002 Best Paper, Aviation Space and Environmental Medicine: Best paper for all issues in 2002
2000 Young Scientist Award, American Society of Biomechanics, Pre-doctoral
1998 Best Student Paper, 38th Stapp Car Crash Conference

EXTERNAL RESEARCH FUNDING:

Total external funding over $55M from 84 active and completed projects with over $20M personal share. All funding shown in total costs including indirect.

1. Biomechanical Evaluation of Equestrian Chest Protectors, United States Hunter Jumper Association and Jaquelin Mars and Jennifer Gates, 2023 – 2024, S. Duma (PI 100%), $825,000.
2. A Low-Cost Modular Blast Acquisition Test System, Department of Defense, 2022 – 2023, P. VandeVord (PI), S. Duma (Co-PI 25%), $68,250.
3. Equestrian Helmet Rating System Development, Jaquelin Mars, Jennifer Gates and the National Hunter Jumper Association, 2021 – 2024, S. Duma (PI 75%) S. Rowson (Co-PI), $450,000.
4. Drone Head Impact Testing for FAA Flight Approval, State Farm and Wing, 2020 – 2024, S. Rowson (PI), S. Duma (Co-PI 10%), $660,000.
5. Sporting Helmet Testing and Evaluation for the Virginia Tech Helmet Ratings, Industry Sponsors in all sports, 2018 – 2028, S. Rowson (PI), S. Duma (Co-PI 33%), $1,350,000.
6. Nerf Toy Design Eye and Face Injury Risk Analysis, Hasbro Corporation, 2019 – 2024, S. Duma (PI 100%), $80,000.
7. Head Impact Response from UAS Drone Impact, Federal Aviation Administration, 2016 – 2022, S. Duma (PI 50%) S. Rowson (Co-PI) M. Blanks (Co-PI), $55,000.
8. Injury Biomechanics Research, National Highway Traffic Safety Administration, 2016 – 2021, W. Hardy (PI) S. Duma (Co-PI 5%) A. Kemper (Co-PI) H. Gabler (Co-PI), $5,280,000.
9. National Football League Helmet Research, NFL, 2016 – 2017, S. Rowson (PI) S. Duma (Co-PI 20%) B. Rowson (Co-PI), $65,000.
10. Eye Injury Risk from Small Aerial Drone Toys, Toys-R-Us, 2016, S. Duma (PI 100%), $7,500.
11. Biomechanical Basis of Pediatric mTBI Due to Sports Related Concussion, National Institutes of Health Bioengineering Research Partnership (NINDS R01NS094410), 2015 – 2021, S. Duma (PI 50%) S. Rowson (Co-PI), $3,306,869.
12. Clinical Study Core, NCAA – DOD Grand Alliance, 2015 – 2021, S. Duma (PI 50%) S. Rowson (Co-PI), $238,484.
13. Development of Sensor STAR for Biomechanical Sensor Ratings, The Lewis Family Foundation, 2015 – 2024, S. Duma (PI 50%), S. Rowson (Co-PI), $250,000.
14. Advanced Research Core Head Impact Technology, NCAA – DOD Grand Alliance, 2014 – 2021, S. Duma (PI 33%) S. Rowson (Co-PI) S. LaConte (Co-PI), $1,011,746.
15. Assessing the Need for Bicycle Helmet Ratings, Insurance Institute for Highway Safety, 2014-2016, S. Rowson (PI) S. Duma (Co-PI 50%), $125,000.
16. REU Site: A Multiscale Approach to Biomechanics, National Science Foundation, 2014 – 2017, P. VandeVord (PI) S. Duma (Co-PI 9%) H. Gabler (Co-PI) S. Rowson (Co-PI) A. Kemper (Co-PI), Hardy (Co-PI), $375,000.
17. Head, Neck, and Chest Injury Prevention for Soldiers, Department of Defense Part III, 2013 – 2016, S. Duma (PI 50%) A. Kemper (Co-PI) P. VandeVord (Co-PI) S. Rowson (Co-PI) W. Hardy (Co-PI) H. Gabler (Co-PI), $4,000,000.
18. Investigation of Thoracic and Abdominal Loading Due to Different Safety Restraint Conditions Using ATDs and PMHSs – DEQ II, Toyota Motor Corporation, 2013 – 2015, A. Kemper (PI) S. Duma (CO-PI 10%), $645,000.

19. Falling Man Risk Assessment with High Explosives Part II, Department of Energy, 2013 -2014, A. Kemper (PI) S. Duma (Co-PI), $150,000.
20. Investigation of DEQ Thoracic Injury Criteria, Toyota Motor Corporation, 2012 – 2013, A. Kemper (PI) S. Duma (CO-PI 20%), $190,700.
21. Injury Mitigation Partnership for Blast Loading, Department of Defense, 2012 – 2013, W. Hardy (PI) S. Duma (Co-PI 5%) H Gabler (Co-PI), $2,473,991.
22. PMHS and ATD with Generic Hull Blast Testing Phase 4.2, Department of Defense, 2011 – 2013, W. Hardy (PI) S. Duma (Co-PI 5%) H. Gabler (Co-PI), $1,233,591.
23. PMHS Testing of PPE and Restraint Systems under Free Air Blast Conditions, Department of Defense, 2011, W. Hardy (PI) S. Duma (Co-PI 5%) H. Gabler (Co-PI), VendeVord (Co-PI), $1,600,000.
24. PMHS and ATD Testing with Generic Hull under Free Air Blast Conditions, Department of Defense, 2011, W. Hardy (PI) S. Duma (Co-PI 5%) H. Gabler (Co-PI), VendeVord (Co-PI), $300,000.
25. Falling Man Risk Assessment with High Explosives, Department of Energy, 2011 – 2012, T. Lockhart (PI) A. Kemper (Co-PI) S. Duma (Co-PI 10%), $250,000.
26. Investigation of Abdominal Injury Patterns, Mechanisms, and Tolerances, Toyota Motor Corporation, 2011 – 2014, W. Hardy (PI) S. Duma (Co-PI 10%) H. Gabler (Co-PI), $750,000.
27. Head, Neck, and Chest Injury Prevention for Soldiers, Department of Defense Part II, 2010 – 2013, S. Duma (PI 60%), W. Hardy (Co-PI), H. Gabler (Co-PI) $3,200,000.
28. Crash Injury Research and Engineering Network, National Highway Traffic Safety Administration, 2010 – 2015, W. Meredith (PI) J. Stitzel (Co-PI) S. Duma (Co-PI 2%), $2,500,000.
29. Child Head Injury Biomechanics and Toy Design, Hasbro Corporation, 2010 – 2011, S. Duma (PI 100%), $50,000.
30. Improved Automobile Safety through Experimental Modeling, National Highway Traffic Safety Administration, 2009 – 2014, J. Stitzel (PI) W. Hardy (Co-PI) S Duma (Co-PI 13%), $3,000,000.
31. Lateral Facial Fracture Injury Risk Functions, Department of Defense, 2009 – 2012, S. Duma (PI) W. Hardy (Co-PI), $350,000.
32. Sled Grant Addition, Department of Defense, 2009 – 2012, S. Duma (PI 60%), W. Hardy (Co-PI 90%), H. Gabler (Co-PI), $150,000.
33. Dynamic Eye Injury Criteria Development with High-rate Equipment, Department of Defense, 2009 – 2012, S. Duma (PI 100%), $150,000.
34. Advanced Instrumented Eye for Blast Injury Analysis, Department of Defense, 2009 – 2011, S. Duma (PI 100%), $450,000.
35. Internal Organ Kinematics in High Rate Impact Loading Conditions, Toyota Motor Corporation, 2009, W. Hardy (PI) S. Duma (Co-PI 5%), $210,000.
36. Head Acceleration Data Analysis Additional Year, Toyota Central Research and Development Laboratories, 2009, S. Duma (PI 100%), $10,000.

37. Eye Injury Risk Functions for Human and FOCUS Eyes, Department of Defense, 2008 – 2010, S. Duma (PI 100%), $450,000.
38. Full Body Model Center of Expertise, Global Human Body Modeling Consortium, 2008 – 2011, J. Stitzel (PI) W. Hardy (Co-PI) S. Duma (Co-PI 5%), $3,385,000.
39. Brain Injury Data Analysis, Via College of Osteopathic Medicine, 2008 – 2011, S. Duma (PI 100%), $75,000.
40. Biomechanical Basis for Mild Traumatic Brain Injury, National Institutes of Health Bioengineering Research Partnership (NICHD R01HD048638), 2007 – 2013, R. Greenwald (PI) J. Crisco (Co-PI), S. Duma (Co-PI 25%), $4,771,000.
41. Head, Neck, and Chest Injury Prevention for Soldiers, Department of Defense Part I, 2007 – 2010, S. Duma (PI 100%), $3,200,000.
42. Research for Thoracic Internal Organ Injury, Toyota Motor Corporation, 2007 – 2009, S. Duma (PI 50%) H. Gabler (Co-PI) J. Stitzel (Co-PI), $420,000.
43. Muscle Biomechanics and Active Tensing for Automobile Safety, Toyota Central Research and Development Laboratories, 2008 – 2009, S. Duma (PI 80%) M. Madigan (Co-PI), $300,000.
44. Brain Injury Validation Data Collection, Toyota Central Research and Development Laboratories, 2008 – 2009, S. Duma (PI 100%), $65,000.
45. Brain Injury Validation Data Sensor Development, Toyota Central Research and Development Laboratories, 2007 – 2008, S. Duma (PI 100%), $130,000.
46. Head Accelerations and Child Skull Geometry Investigation, National Highway Traffic Safety Administration, 2007 – 2009, J. Stitzel (PI) S. Duma (Co-PI 50%), $400,000.
47. Material Properties and Geometry of the Pregnant Female, Ford Motor Company, 2007 – 2009, S. Duma (PI 50%) J. Stitzel (Co-PI), $120,000.
48. Impact Fracture Analysis of Plastic Eyeglass Lenses, TriboFilm Research Incorporated (NIH – SBIR), 2006, S. Duma (PI 100%), $60,000.
49. Crash Injury Research and Engineering Network, National Highway Traffic Safety Administration, 2005 – 2010, W. Meredith (PI) J. Stitzel (Co-PI) S. Duma (Co-PI 2%) $2,100,000.
50. The Effects of Football Neck Protective Devices on Neck Loads, The Kerr Foundation: Part II, 2005 – 2006, S. Duma (PI 100%), $10,000.
51. The Effects of Football Neck Protective Devices on Neck Loads, The Kerr Foundation, 2005 – 2006, S. Duma (PI 100%), $55,000.
52. Head and Neck Injury Prevention: Biomechanical Analysis of the Eye, Face, Brain, and Neck, Department of Defense, 2005 – 2008, S. Duma (PI 100%), $1,002,000.
53. Pelvic and Thoracic Injury Biomechanics in Side Impact, Toyota Motor Corporation, 2005 – 2007, S. Duma (PI 100%), $592,000.
54. Mechanical Properties of Human Ribs, Ford Motor Corporation, 2005 – 2007, S. Duma (PI 100%), $120,000.

55. Dynamic Tissue Properties for the Pregnant Occupant, Toyota Motor Corporation, 2005 – 2007, S. Duma (PI 100%), $125,000.
56. Biodynamic Simulations of Musculoskeletal Injuries to the Human Neck Due to Added Head-Supported Mass Worn by Soldiers in Military Environments Part II, Department of Defense, 2005, S. Duma (PI 100%), $31,750.
57. Thoracic Response to Dynamic Belt Loading, TRW International, 2004, S. Duma (PI 100%), $20,000.
58. Human Tibia and Humerus Material Property Characterization, Toyota Motor Corporation, 2004, S. Duma (PI 100%), $29,000.
59. Summer Research Intern Program, General Motors, 2004, S. Duma (PI 100%), $4,000.
60. Characterization of the Human Spine and Pelvis, Toyota Motor Corporation, 2004 – 2005, S. Duma (PI 100%), $334,000.
61. Abdominal Response and Characterization to Blunt Impact, Autoliv Corporation France, 2004 – 2006, S. Duma (PI 100%), $150,000.
62. Carotid Artery Modeling and Injury Prediction, Ford Motor Company, 2003 – 2006, S. Duma (PI 75%) J. Stitzel (Co-PI), $165,000.
63. Cortical Bone Testing and Modeling of Seatbelt Loading, Toyota Motor Corporation, 2003 – 2004, S. Duma (PI 100%), $310,000.
64. Effects of Orbital Muscles on Eye Injury Biomechanics, National Highway Traffic Safety Administration, 2002 – 2003, S. Duma (PI 90%) I. Herring (Co-PI), $150,000.
65. Eye Rupture from Internal Pressure, Department of Defense, 2003, S. Duma (PI 100%), 14,400.
66. Eye Injury Risk Analysis Continuation, Department of Defense, 2002, S. Duma (PI 100%), $4,600.
67. Biodynamic Simulations of Musculoskeletal Injuries to the Human Neck Due to Added Head-Supported Mass Worn by Soldiers in Military Environments, Department of Defense, 2002 – 2004, S. Duma (PI 100%), $90,097.
68. Material Properties of the Elderly Thorax, Toyota Motor Corporation, 2002 – 2003, S. Duma (PI 100%), $128,000.
69. Vision Characteristics in the Aging Population, Toyota Motor Corporation, 2002 – 2003, T. Lockhard (PI) S. Duma (PI 50%), $118,000.
70. Mechanical Spring Design for the Treatment of Craniosynostosis, Wake Forest University, 2002 – 2003, S. Duma (PI 100%), $25,000.
71. The Effects of Scleral Displacement on Lens Accommodation, The Jeffress Foundation, 2002, S. Duma (PI 75%) I. Herring (Co-PI), $33,000.
72. Impact Tolerance of the Femur, Autoliv Corporation France, 2002, S. Duma (PI 100%), $85,000.
73. Upper Extremity Impact from Side Airbags, Department of Defense, 2001 – 2002, S. Duma (PI 100%), $44,000.

74. Neck Injuries from Head Supported Masses, Department of Defense, 2001 – 2002, S. Duma (PI 100%), $5,500.
75. Evaluation of Airbag Induced Skin Abrasions, Autoliv Corporation North America, 2001, S. Duma (PI 100%), $38,300.
76. Ocular and Facial Injury Risk with Helmet Mounted Displays, Department of Defense, 2000 – 2001, S. Duma (PI 100%), $76,000.
77. NASS Investigation of Burn Injuries, Autoliv Corporation North America, 2001, S. Duma (PI 100%), $5,300.
78. NASS Investigation of Rear Seat Occupants, Autoliv Corporation North America, 2001, S. Duma (PI 100%), $9,100.
79. Axial Loading of the Human Spine, Autoliv Corporation North America, 2001, S. Duma (PI 100%), $24,100.
80. Vertical Loading from Inflatable Seat Air Bag, Autoliv Corporation North America, 2001, S. Duma (PI 100%), $24,100.
81. Upper Extremity Joint Injury Tolerance Study, Honda Motor Corporation, 1999 – 2000, J. Crandall (PI) S. Duma (Co-PI 50%), $412,000.
82. Injury Evaluation of the Cockpit Air Bag System, Department of Defence, 1998 – 1999, J. Crandall (PI) S. Duma (Co-PI 50%), $14,500.
83. Evaluation of Eye Injury Risk from Prototype Air Bags, Ford Motor Company, 1998, S. Duma (PI 100%), $34,750.
84. Baseball Induced Eye Injuries, Tuffs University School of Medicine, 1998, S. Duma (PI 100%), $6,500.

GRADUATE STUDENT SUPERVISION

Supervised 27 M.S. and eight Ph.D. students, five are in tenure track faculty positions

Bethany Rowson, PhD Dissertation: Hockey STAR Evaluation System, 2016
Currently Research Scientist, Virginia Tech

Vanessa Alphonse, PhD Dissertation: Eye Injury Biomechanics and Surrogate Head Models, 2016
Currently Research Scientist, Applied Physics Laboratory, Johns Hopkins University

Anna MacAllister, MS Thesis: Hockey Helmet Testing and Concussion Evaluation, 2014

Tyler Young, MS Thesis: Youth Football Practice Patterns and Head Accelerations, 2013

Ray Daniel, MS Thesis: Head Acceleration in Youth Football, 2012

Vanessa Alphonse, MS Thesis: Eye Injuries from Blast, 2012

Steve Rowson, PhD Dissertation: Head Injury Biomechanics, 2011
Currently Associate Professor, Virginia Tech Biomedical Engineering and Mechanics

Tina Smeitz, MS Thesis: Skull deformation analysis, 2011

Jeff Beyer, MS Thesis: Concussion risk in Baseball, 2011

Stephanie Beeman, MS Thesis: Muscle activation in auto-safety, 2011

Andrew Kemper, PhD Dissertation: Biomechanics of Human Thorax, 2010
Currently Assistant Professor, Virginia Tech Biomedical Engineering and Mechanics

Anthony Santago, MS Thesis: Human Liver Tissue Properties, 2010

Joseph Cormier, PhD Dissertation, Facial Fracture Biomechanics, 2009
Currently Senior Consultant, BioCore NFL Research

Sarah Manoogian, PhD Dissertation: Pregnant Occupant Biomechanics, 2008
Currently Assistant Professor, Bucknell University Biomedical Engineering

Steve Rowson, MS Thesis: 6DOF Helmet Sensors, 2008

Eric Kennedy, PhD Dissertation: FOCUS Headform for Eye and Facial Injuries, 2007
Currently Associate Professor, Bucknell University Biomedical Engineering

David McNeely, MS Thesis, Analysis of Neck Loading in Football Impacts, 2006

Amber Rath, MS Thesis, Effects of Orbital Muscles on Eye Injury Biomechanics, 2005

Andrew Kemper, MS Thesis, Material Properties of the Human Rib Cortical Bone, 2005

Sarah Manoogian, MS Thesis, Head Accelerations in Collegiate Football, 2005

Bill Bussone, MS Thesis, Everyday Accelerations of the Human Head, 2005

Gail Hansen, MS Thesis, Hyperextension Biomechanics of the Elbow Joint, 2004

Eric Kennedy, MS Thesis, Dynamic Bending Tolerance of the Human Femur, 2004

William Hurst, MS Thesis, Mechanical Springs for Cranyiosynostosis, 2003

Katherine Voorhies, MS Thesis, Dynamic Rupture Stress for Human and Porcine Eyes, 2003

Joseph Cormier, MS Thesis, Microstructural and Mechanical Properties of Human Ribs, 2003

Dave Tordanato, MS Thesis, Effects of Freezing on the Dynamic Properties of Cartilage, 2003

Joel Stitzel, PhD Dissertation, Mechanical Properties of Human Rib Cortical Bone, 2003
Currently Professor, Wake Forest University Biomedical Engineering

Mary Jernigan, MS Thesis, Analysis and Modeling of Injuries in Automobile Crashes, May, 2002

David Moorcroft, MS Thesis, A Finite Element Model of the Pregnant Female Occupant: Analysis of Injury Mechanisms and Restraint Systems, August, 2002

Eric Power, MS Thesis, A Nonlinear Finite Element Model of the Human Eye to Investigate Ocular Injuries from Night Vision Goggles, May, 2001

TEACHING EXPERIENCE

Biomedical Engineering 2004: Concussion Perspectives: Medical, Scientific, and Societal Perspectives

Developed course as curriculum for liberal education and pathways course
Over 2,000 students take the course each year from any department and college at Virginia Tech

Biomedical Engineering 3004: Helmet Design
Developed course as curriculum for liberal education and pathways course
Over 2,000 students take the course each year from any department and college at Virginia Tech

Mechanical Engineering 3614: Mechanical Design
Mechanical Engineering 4015/4016: Senior Design (hip protection, helmet design)
Mechanical Engineering 4754: Impact Biomechanics (developed course)

Engineering Science and Mechanics 4015/4016: Senior Design (baseball pitcher helmet design)

Biomedical Engineering and Sciences 3134: Introduction to Biomedical Engineering (guest lecture)
Biomedical Engineering and Sciences 5164: Advanced Impact Biomechanics (developed course)
Biomedical Engineering and Sciences 5184: Injury Physiology (developed course)

Mechanical Engineering 5994: MS Thesis and Research
Mechanical Engineering 7994: PhD Dissertation and Research
Biomedical Engineering and Sciences 5994: MS Thesis and Research
Biomedical Engineering and Sciences 7994: PhD Dissertation and Research

As Department Head, oversaw the creation of a minor in Biomedical Engineering (approved spring 2014) and the full undergraduate degree in Biomedical Engineering (approved spring 2017). Dr. Pamela VanedVord was directly responsible for the development of these programs as the Associated Department Head, and she deserves the credit for their success.

PROFESSIONAL SOCIETY MEMBERSHIPS

2017-present National Neurotrauma Society
2017-present Women in Neurotrauma Research (WiNTR)
2009-present Biomedical Engineering Society
2009-present American Institute for Medical and Biological Engineering
2002-present American Society of Mechanical Engineers
2000-present American Society for Engineering Education
1998-present Society of Automotive Engineers
1998-present American Society of Biomechanics
1997-present Association for the Advancement of Automotive Medicine

EDITORIAL AND MANUSCRIPT REVIEWER ACTIVITIES

2009-2024 Editor-in-Chief, Annals of Biomedical Engineering
2000-2009 Associate Editor, Accident Analysis and Prevention
1999-2005 Scientific Committee, Association for the Advancement of Automotive Medicine
2000-present Manuscript reviewer: Journal of Biomechanics, Journal of Biomechanical Engineering, Annals of Biomedical Engineering, Archives of Ophthalmology

2000-present Conference manuscript reviewer: Biomedical Engineering Society, International Research Council on the Biomechanics of Impact, Association for the Advancement of Automotive Medicine, American Society of Biomechanics

PATENT ACTIVITY

Duma BG, Rowson S, Begonia M, Duma SM "Optimized Whitewater Helmet Design" Provisional Patent filed 2022.

Duma LA, Rowson S, Begonia M, Miller B, Duma SM "Equestrian Helmet STAR System" Provisional Patent filed 2022.

Duma BG, Rowson S, Begonia M, Duma SM "Whitewater Helmet STAR System" Provisional Patent awarded, Utility Patent Submitted 2022.

Duma SM, Rowson S, MCNally C, "A methodology for assessing the biomechanical performance of helmets," VTIP 15-007 (US Patent 9,797,821 B2) October 24, 2017.

Tamura A, Duma SM, "A control methodology of pedestrian kinematics using active hood lift system," VTIP 10-113 (US Patent 8,700,257 B2) April 15, 2014.

PUBLICATIONS

Google Scholar: 15,563 citations, h-index 64, i10-index 210 as of March 21, 2025
http://scholar.google.com/citations?user=cZhQN8YAAAAJ&hl=en

Total Publications:	*577*
Refereed Journal Papers:	213
Refereed Conference Papers (Full Length):	115
Conference Abstracts:	244
Books:	6
Book Chapters:	3

Papers in Refereed Journals

1. AJ Boltz, LB Lempke, RA Syrydiuk, S Duma, P Pasquina, TW McAllister, Association of sport helmet status on concussion presentation and recovery in male collegiate student-athletes. Annals of biomedical engineering 52 (10), 2884-2896, 2024.
2. SP Sawlani, JT Goldman, T Babikian, DL McArthur, D Polster, M McCrea, SM Duma, Association of premorbid anxiety and depression symptoms in concussion recovery in collegiate student-athletes. Sports health, 19417381241255308, 2024.
3. JA King, LD Nelson, K Cheever, B Brett, J Gliedt, A Szabo, H Dong, SM Duma, The prevalence and influence of new or worsened neck pain after a sport-related concussion in collegiate athletes: a study from the CARE Consortium. The American journal of sports medicine, 03635465241247212, 2024.
4. E Simpson, JL Reiter, J Ren, Z Zhang, KN Nudelman, LD Riggen Jr, SM Duma, Gene expression alterations in peripheral blood following sport-related concussion in a prospective cohort of collegiate athletes. Sports medicine 54 (4), 1021-1032, 2024.
5. G Bertò, LT Rooks, SP Broglio, TA McAllister, MA McCrea, PF Pasquina, SM Duma, Diffusion tensor analysis of white matter tracts is prognostic of persisting post-concussion symptoms in collegiate athletes. Neuroimage: clinical 43, 103646, 2024.
6. JP Mihalik, A Chandran, JR Powell, PR Roby, BD Stemper, AS Shah, SM Duma, Do head injury biomechanics predict injury recovery? British Journal of Sports Medicine 58 (Suppl 1), A38-A39, 2024.
7. E Simpson, JL Reiter, J Ren, Z Zhang, KN Nudelman, LD Riggen Jr, et al. Gene expression alterations in peripheral blood following sport-related concussion in a prospective cohort of collegiate athletes: a Concussion Assessment, Research. Sports Medicine, 1-12, 2023.
8. YC Wu, Q Wen, R Thukral, HC Yang, JM Gill, S Gao, KA Lane, TB Meier, et al. Longitudinal associations between blood biomarkers and white-matter MRI in sport-related concussion: a study of the NCAA-DoD CARE Consortium. Neurology, 1, 2023.
9. R Vorn, C Devoto, TB Meier, C Lai, S Yun, SP Broglio, S Mithani, et al. Are EPB41 and alpha-synuclein diagnostic biomarkers of sport-related concussion? Findings from the NCAA and Department of Defense CARE Consortium. Journal of sport and health science 12 (3), 379-387, 2023.

10. C Devoto, R Vorn, S Mithani, TB Meier, C Lai, SP Broglio, T McAllister, et al. Plasma phosphorylated tau181 as a biomarker of mild traumatic brain injury: findings from THINC and NCAA-DoD CARE Consortium prospective cohorts. Frontiers in Neurology 14(1), 2023.
11. Duma BG, Begonia MT, Miller B, et al, "Whitewater helmet STAR: Evaluation of the biomechanical performance and risk of head injury for whitewater helmets," *Annals of Biomedical Engineering,* 50 (11) 1520 – 1533, 2022.
12. Rowson B, Duma SM, "A review of head injury metrics used in automotive safety and sports protective equipment," *Journal of Biomechanical Engineering* 144 (11), 2022.
13. Vorn R., Devoto C, Meier TB, et al, "Are EPB41 and alpha-synuclein diagnostic biomarkers of sport-related concussion? Findings from the NCAA and Department of Defense CARE Consortium," *Jouranl of Sport and Health Science*, 2022.
14. Seifert J, Shah AS, Harexlak J, Rowson S, Mihalik JP, Riggen L, Duma SM, et al, "Time delta head impact frequency: an analysis on head impact exposure in the lead up to a concussion: findings from the NCAA-DOD Care Consortium," *Annals of Biomedical Engineering*, 1-15, 2022.
15. Vorn R, Mithani S, Devoto C, Meier T, Lai C, Yun S, et al, "Proteomic Profiling of Plasma Biomarker Associated with Return to Sport Following Concussion: Findings from the NCAA and Department of Defense CARE Consortium," *Frontiers in Neurology*, 1353, 2022.
16. Mustafi SM, Yang HC, Harezlak J, et al, "Effects of white-matter tract length in sport-related concussion: a tractography study from the NCAA-DoD CARE Consortium," *Journal of Neurotrauma*, 2022.
17. Choi GB, Smith EP, Duma SM, et al, "Head Impact Exposure in Youth and Collegiate American Football," *Annals of Biomedical Engineering*, 1-10, 2022.
18. Rowson B, Duma SM, "Annals of Biomedical Engineering 2021 Year in Review." *Annals of Biomedical Engineering*, 1-4, 2022.
19. Seifert J, Shah A, Harezlak J, et al, "Elevated Rate of Head Impacts at Time of Injury in Concussed NCAA Division I American Football Players: Findings From the NCAA-DoD CARE Consortium," *Brain Injury*, 36, 65-66, 2022.
20. Stemper BD, Harezlak J, Shah AS, et al, "Association between preseason/regular season head impact exposure and concussion incidence in NCAA football," *Medicine and Science in Sports and Exercise*, 3, 2022.
21. Maerlender A, Smith E, Brolinson PG, et al, "Psychometric properties of the standardized assessment of concussion in youth football: Validity, reliability, and demographic factors," *Applied Neuropsychology: Child*, 10 (4), 377-383, 2021.
22. Rowson B, Duma SM, "Special Issue on Concussions in Sports," *Annals of Biomedical Engineering,* 49 (10), 2673-2676, 1, 2021.
23. Rowson B, Duma SM, "Annals of Biomedical Engineering 2020 Reviewer Recognition," *Annals of Biomedical Engineering*, 49 (5), 1271-1274, 2021.

24. Bethany R, Duma SM, "Annals of Biomedical Engineering 2020 Year in Review," *Annals of Biomedical Engineering*, 49 (4), 1121-1124, 2021.

25. Duma LA, Begonia MT, Miller B, Duma SM, "Proposed injury threshold for drone blade lacerations," *Annals of Biomedical Engineering*, 49 (4), 1125-1127 3, 2021.

26. Maerlender A, Smith E, Brolinson PG, et al, "Neuropsychological change after a single season of head impact exposure in youth football," *Journal of the International Neuropsychological Society*, 27 (2), 113-123, 4, 2021.

27. Giza CC, McCrea M, Huber D, et al, "Assessment of Blood Biomarker Profile After Acute Concussion During Combative Training Among US Military CadetsA Prospective Study From the NCAA and US Department of Defense CARE Consortium," *JAMA Network Open*, 4(2), 2021.

28. McCrea MA, Shah A, Duma SM, et al, "Opportunities for prevention of concussion and repetitive head impact exposure in college football players: a Concussion Assessment, Research, and Education (CARE) Consortium study," *JAMA Neurology*, 2021.

29. Rowson B, Duma SM, King MR, et al, "Citation diversity statement in BMES journals," *Annals of Biomedical Engineering*, 2021.

30. Caccese JB, Houck Z, Kaminski TW, et al, "Estimated age of first exposure to American football and outcome from concussion," *Neurology* 95 (21), e2935-e2944, 2020.

31. Rowson B, Duma SM, "A review of on-field investigations into the biomechanics of concussion in football and translation to head injury mitigation strategies," *Annals of Biomedical Engineering* 48: 2734–2750, 2020.

32. Brett BL, Kramer MD, McCrea MA, et al, "Bifactor Model of the Sport Concussion Assessment Tool Symptom Checklist: Replication and Invariance Across Time in the CARE Consortium Sample," *The American Journal of Sports Medicine* 48 (11), 2783-2795, 2020.

33. Rowson B, Duma SM, "Special issue on concussion biomechanics in football," *Annals of Biomedical Engineering* 48: 2495–2496, 2020.

34. Wu YC, Harezlak J, Elsaid NMH, et al, "Longitudinal white-matter abnormalities in sports-related concussion: A diffusion MRI study," *Neurology* 95 (7), e781-e792, 2020.

35. Mihalik JP, Chandran A, Powell JR, et al, "Do head injury biomechanics predict concussion clinical recovery in college American football players?" *Annals of Biomedical Engineering* 48: 2555-2565, 2020.

36. Pattinson CL, Meier TB, Guedes VA, et al, "Plasma Biomarker Concentrations Associated With Return to Sport Following Sport-Related Concussion in Collegiate Athletes—A Concussion Assessment, Research, and Education," *JAMA Network Open* 3 (8), e2013191-e2013191, 2020.

37. Rowson S, Campolettano ET, Duma SM, et al, "Concussion risk between individual football players: survival analysis of recurrent events and non-events," *Annals of Biomedical Engineering* 48: 2626-2638, 2020.

38. Stemper BD, Shah AS, Mihalik JP, et al, "Do head injury biomechanics predict concussion clinical recovery in college American football players?," *Medicine and Science in Sports and Exercise* 52 (7), 1629-1638, 2020.

39. Rowson B, Duma SM, "Annals of Biomedical Engineering 2019 Year in Review," *Annals of Biomedical Engineering* 48: 1587-1589, 2020.

40. Maerlender A, Smith E, Brolinson PG, et al, "Psychometric properties of the standardized assessment of concussion in youth football: Validity, reliability, and demographic factors," *Applied Neuropsychology*: Child, 6: 1-7, 2020.

41. Brett BL, Wu YC, Mustafi SM, et al, "The association between persistent white-matter abnormalities and repeat injury after sport-related concussion," *Frontiers in Neurology* 10: 1335 - 1345, 2020.

42. Maerlender AC, Brolinson PG, Crisco JJ, et al, "Neuropsychological Change After a Single Season of Head Impact Exposure in Youth Football," *Journal of the International Neuropsychological Society* 27(2): 113 – 123, 2020.

43. Campolettano ET, Gellner RA, Smith EP, et al, "Development of a concussion risk function for a youth population using head linear and rotational acceleration," *Annals of Biomedical Engineering* 48: 92-103 2020.

44. Brett B, Bobholz S, Espana L, et al, "The effects of concussion history and cumulative contact sport exposure on brain morphometry in collegiate athletes," *Journal of Neurotrauma*, 36 (13), A63-A63, 2019.

45. Klein AP, Tetzlaff JE, Bonis JM, et al, "Prevalence of potentially clinically significant magnetic resonance imaging findings in athletes with and without sport-related concussion," *Journal of Neurotrauma* 36 (11), 1776-1785, 2019.

46. Rowson B, Duma SM, "Annals of Biomedical Engineering 2018 Year in Review," *Annals of Biomedical Engineering* 47 (12), 2343-2345, 2019.

47. Alois J, Bellamkonda S, Campolettano ET, et al, "Do American youth football players intentionally use their heads for high-magnitude impacts?" *The American Journal of Sports Medicine* 47 (14), 3498-3504, 2019.

48. Rowson B, Stitzel JD, Duma SM, "Special Issue on the NCAA-DoD CARE Consortium Research," *Annals of Biomedical Engineering* 47 (10), 2045-2047, 2019.

49. Stemper BD, Shah AS, Harezlak J, et al, "Repetitive head impact exposure in college football following an NCAA rule change to eliminate two-a-day preseason practices: a study from the NCAA-DoD CARE Consortium," *Annals of Biomedical Engineering* 47 (10), 2073-2085, 2019.

50. Rowson S, Campolettano ET, Duma SM et al, "Accounting for variance in concussion tolerance between individuals: comparing head accelerations between concussed and physically matched control subjects," *Annals of Biomedical Engineering* 47 (10), 2048-2056, 2019.

51. Campolettano ET, Rowson S, Duma SM, et al, "Factors affecting head impact exposure in college football practices: a multi-institutional study," *Annals of Biomedical Engineering* 47 (10), 2086-2093, 2019.

52. Stemper BD, Shah AS, Harezlak J, et al, “Comparison of head impact exposure between concussed football athletes and matched controls: evidence for a possible second mechanism of sport-related concussion,” *Annals of Biomedical Engineering* 47 (10), 2057-2072, 2019.

53. Mustafi SM, Harezlak J, Koch KM, et al “Acute white-matter abnormalities in sports-related concussion: a diffusion tensor imaging study from the NCAA-DoD CARE Consortium,” *Journal of Neurotrauma* 35 (22) pp 2653-2664, 2018.

54. Stemper BD, Shah AS, Harezlak J, et al, “Comparison of head impact exposure between concussed football athletes and matched controls: evidence for a possible second mechanism of sport-related concussion,” *Annals of Biomedical Engineering*, pp 1-16, 2018.

55. Bellamkonda S, Woodward SJ, Campolettano, et al, “Head impact exposure in practices correlates with exposure in games for youth players,” *Journal of Applied Biomechanics* 34 (5) pp 354-360, 2018.

56. Tyson AM, Duma SM, Rowson S, “Laboratory evaluation of low-cost wearable sensors for measuring head impacts in sports,” *Journal of Applied Biomechanics* 34 (4) pp 320-326, 2018.

57. Nencka AS, Meier TB, Wang Y, et al, “Stability of MRI metrics in the advanced research core of the NCAA-DoD concussion assessment, research and education (CARE) consortium,” *Brain Imaging and Behavior* 12 (4) pp 1121-1140, 2018.

58. Weber ML, Dean JL, Hoffman NL, et al, “Influences of mental illness, current psychological state, and concussion history on baseline concussion assessment performance,” *American Journal of Sports Medicine* 46 (7) pp 1742-1751, 2018.

59. Beckwith J, Zhao W, Ji S, et al, “Estimated brain tissue response following impacts associated with and without diagnosed concussion,” *Annals of Biomedical Engineering* 46 (6) pp 819-830, 2018.

60. Asken BM, Bauer RM, Guskiewicz KM, et al, “Immediate removal from activity after sport-related concussion is associated with shorter clinical recovery and less severe symptoms in collegiate student-athletes,” *American Journal of Sports Medicine* 46 (6) pp 1465-1474, 2018.

61. Tyson AM, Duma SM, and Rowson S, “Laboratory evaluation of low-cost wearable sensors for measuring head impacts in sports,” *Journal of Applied Biomechanics*, vol. 34(4) pp. 320-326, 2018.

62. Rowson S, Duma SM, Stemper BD, et al, “Correlation of concussion symptom profile with head impact biomechanics: a case for individual-specific injury tolerance,” *Journal of Neurotrauma*, vol. 35(4), pp. 681-690, 2018.

63. Rowson S, Duma SM, Stemper BD, et al, “Correlation of concussion symptom profile with head impact biomechanics: a case for individual-specific injury tolerance,” *Journal of Neurotrauma*, 35(4), pp. 681-690, 2018.

64. Campolettano ET, Bland ML, Gellner RA, et al, “Ranges of injury risks associated with impact from unmanned aircraft systems,” *Annals of Biomedical Engineering*, vol. 45(12), pp. 2733-2741, 2017.

65. Stemper B, Shah A, Chiariello R, et al, “Subconcussive head impact history as a factor in concussion onset,” *Brain Injury*, 31 (6-7), 899-900, 2017, 2017.

66. O'Connor KL, Rowson S, Duma SM, and Broglio SP, "Head-impact-measurement devices: a systematic review," *Journal of Athletic Training*, vol. 52(3), pp. 206-227, 2017.

67. Sanchez E, Gabler L, Rowson B, et al, "Brain Strain Patterns Associated with Football Impact Reconstructions," *Journal of Neurotrauma*, 34 (13), A30-A31, 2017.

68. Rowson S, Bland ML, Campolettano ET, Press JN, Rowson B, Smith JA, Sproule DW, Tyson AM, and Duma SM, "Biomechanical perspectives on concussion in sport," *Sports Medicine and Arthroscopy Review*, vol. 24(3), pp. 100-107, 2016.

69. Broglio SP, Baldwin G, Castellani RJ, et al, "Summary of the 2015 University of Michigan sport concussion summit," *Concussion*, 1 (4), CNC23, 2016.

70. Beeman SM, Kemper AR, and Duma SM. "Neck forces and moments of human volunteers and post mortem human surrogates in low-speed frontal sled tests," *Traffic Injury Prevention*, vol. 17(sup1), pp. 141-149, 2016.

71. Kemper AR, Beeman SM, Porta DJ, and Duma SM. "Non-censored rib fracture data during frontal PMHS sled testing," *Traffic Injury Prevention,* 17(sup1), pp. 131-140, 2016.

72. Campolettano ET, Rowson S, and Duma SM, "Drill-specific head impact exposure in youth football practice," *Journal of Neurosurgery: Pediatrics*, vol. 18(5), pp. 536-541, 2016.

73. Maerlender AC, Masterson CJ, James, TD, Beckwith J, Brolinson PG, Crisco J, Duma S, Flashman LA, Greenwald R, Rowson S, Wilcox B, and McAllister TW, "Test-retest, retest, and retest: growth curve models of repeat testing with immediate post-concussion assessment and cognitive testing (ImPACT)," *Journal of Clinical and Experimental Neuropsychology*, vol. 38(8), pp. 869-874, 2016.

74. Rowson B, Rowson S, and Duma SM, "Hockey STAR: A methodology for assessing the biomechanical performance of hockey helmets," *Annals of Biomedical Engineering*, vol. 43(10), pp. 2429-2443, 2015.

75. Cobb BR, MacAlister A, Young TJ, Kemper AR, Rowson S, and Duma SM, "Quantitative comparison of Hybrid III and National Operating Committee on Standards for Athletic Equipment headform shape characteristics and implications on football helmet fit," *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*, vol. 229(1), pp. 39-46, 2015.

76. Danelson KA, Golman AJ, Kemper AR, Gayzik FS, Gabler HC, Duma SM, and Stitzel JD, "Finite element comparison of human and Hybrid III responses in a frontal impact," *Accident Analysis and Prevention*, vol. 85, pp. 125–156, 2015.

77. Kemper AR, Beeman SM, Madigan ML, and Duma SM, "Human occupants in low-speed frontal sled tests: effects of pre-impact bracing on chest compression, reaction forces, and subject acceleration," *Traffic Injury Prevention*, vol. 15(sup1), pp. S141-S150, 2014.

78. Daniel RW, Rowson S, and Duma SM, "Head impact exposure in youth football: middle school ages 12 to 14 years," *Journal of Biomechanical Engineering*, vol. 136(9), pp. 094501, 2014.

79. Rowson S, Duma SM, Greenwald RM, Beckwith JG, Chu JJ, Guskiewicz KM, Mihalik JP, Crisco JJ, Wilcox BJ, McAllister TW, Maerlender AC, Broglio SP, Schnebel B, Anderson S,

and Brolinson PG, “Letters to the editor: football helmet design and concussion – response,” *Journal of Neurosurgery*, vol. 121(2), pp. 492-494, 2014.

80. Rowson S, Duma SM, Greenwald RM, Beckwith JG, Chu JJ, Guskiewicz KM, Mihalik JP, Crisco JJ, Wilcox BJ, McAllister TW, Maerlender AC, Broglio SP, Schnebel B, Anderson S, and Brolinson PG, “Can helmet design reduce the risk of concussion in football?” *Journal of Neurosurgery*, vol. 120(4), pp. 919-922, 2014.

81. Duma SM and Rowson S, “RE: On the accuracy of the Head Impact Telemetry (HIT) System used in football helmets,” *Journal of Biomechanics*, vol. 47(6), pp. 1557-1558, 2014.

82. Young TJ, Daniel RW, Rowson S, and Duma SM, "Head impact exposure in youth football: elementary school ages 7-8 years and the effect of returning players," *Clinical Journal of Sport Medicine* vol. 24(5), pp. 416-421, 2014.

83. Kemper AR, Brolinson PG, Seimetz CN, and Duma SM, “Re: Re: An investigation of cranial motion through a review of biomechanically based skull deformation literature,” *International Journal of Osteopathic Medicine*, vol. 16(3), pp. 180–183, 2013.

84. Kemper AR., Santago AC, Stitzel JD, Sparks JL, and Duma SM, "Effect of strain rate on the material properties of human liver parenchyma in unconfined compression," *Journal of Biomechanical Engineering* vol. 135(10), pp. 104503, 2013.

85. Cobb BR, Urban JE, Davenport EM, Rowson S, Duma SM, Maldjian JA, Whitlow CT, Powers AK, and Stitzel JD, “Head impact exposure in youth football: elementary school ages 9-12 years and the effect of practice structure,” *Annals of Biomedical Engineering*, vol. 41(12), pp. 2463-2473, 2013.

86. Rowson S, Daniel RW, and Duma SM, “Biomechanical performance of leather and modern football helmets,” *Journal of Neurosurgery*, vol. 119(3), pp. 805-809, 2013.

87. Rowson S, Daniel RW, and Duma SM, “Editorial: leather football helmets – response,” *Journal of Neurosurgery*, vol. 119(3), pp. 803-804, 2013.

88. Duma SM, Rowson S, Cobb B, MacAlister A, Young T, and Daniel R, “Effectiveness of helmets in the reduction of sports-related concussions in youth,” *Institute of Medicine, Commissioned paper by the Committee on Sports-Related Concussion in Youth*, 2013.

89. Rowson S and Duma SM, “Brain injury prediction: assessing the combined probability of concussion using linear and rotational head acceleration,” *Annals of Biomedical Engineering*, vol. 41(5), pp. 873-82, 2013.

90. Beeman SM, Kemper AR, Madigan ML, and Duma SM, “Kinetic and kinematic responses of post mortem human surrogates and the Hybrid III ATD in high-speed frontal sled tests,” *Accident Analysis and Prevention,* vol. 55, pp. 34–47, 2013.

91. Beckwith JG, Greenwald RM, Chu JJ, Crisco JJ, Rowson S, Duma SM, Broglio SP, McAllister TW, Guskiewicz KM, Mihalik JP, Anderson S, Schnebel B, Brolinson PG, Lund B, and Collins MW, “Head impact exposure sustained by football players on days of diagnosed concussion,” *Medicine and Science in Sports and Exercise*, vol. 45(4), pp. 737-746, 2013.

92. Beckwith JG, Greenwald RM, Chu JJ, Crisco JJ, Rowson S, Duma SM, Broglio SP, McAllister TW, Guskiewicz KM, Mihalik JP, Anderson S, Schnebel B, Brolinson PG, Lund B, and

Collins MW, “Timing of concussion diagnosis is related to head impact exposure prior to injury,” *Medicine and Science in Sports and Exercise*, vol. 45(4), pp. 747-54, 2013.

93. Rowson S and Duma SM, “The temperature inside football helmets during head impact: a five year study of collegiate football games,” *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*, vol. 227(1), pp. 12-19, 2013.

94. Rowson S and Duma SM, “The Virginia Tech response,” *Annals of Biomedical Engineering*, vol. 40(12), pp. 2512-2518, 2012.

95. Daniel RW, Rowson S, and Duma SM, “Head impact exposure in youth football,” *Annals of Biomedical Engineering*, vol. 40(4), pp. 976-981, 2012.

96. Alphonse VD, Kemper AR, Strom BT, Beeman SM, and Duma SM, “Exposure to fireworks and eye injuries – reply,” *Journal of the American Medical Association*, vol. 308(15), pp. 1523-1524, 2012.

97. Duhaime AC, Beckwith JG, Maerlender AC, McAllister TW, Crisco JJ, Duma SM, Brolinson PG, Rowson S, Flashman LA, Chu JJ, and Greenwald RM, “Spectrum of acute clinical characteristics of diagnosed concussions in college athletes wearing instrumented helmets,” *Journal of Neurosurgery*, vol. 117(6), pp. 1092-1099, 2012.

98. Beeman SM, Kemper AR, Madigan ML, Franck CT, and Loftus SC, “Occupant kinematics in low-speed frontal sled tests: human volunteers, Hybrid III ATD, and PMHS,” *Accident Analysis and Prevention*, vol. 47, pp. 128-139, 2012.

99. Kemper AR, Santago AC, Stitzel JD, Sparks JL, and Duma SM, “Biomechanical response of human spleen in tensile loading,” *Journal of Biomechanics*, vol. 45(2), pp. 348-355, 2012.

100. Seimetz CN, Kemper AR, and Duma SM, “An investigation of cranial motion through a review of biomechanically based skull deformation literature,” *International Journal of Osteopathic Medicine,* vol. 15(4), pp. 152-165, 2012.

101. Manoogian SJ, Bisplinghoff JA, Kemper AR, and Duma SM, "Dynamic material properties of the pregnant human uterus," *Journal of Biomechanics*, vol. 45(9), pp. 1724-1727, 2012.

102. Duma SM, Bisplingoff JA, Senge DM, McNally C, and Alphonse VD, “Eye injury risk from water stream impact: biomechanically based design parameters for water toy and park design,” *Current Eye Research*, vol. 37(4), pp. 279-285, 2012.

103. Alphonse VD, Kemper AR, Strom BT, Beeman SM, and Duma SM, "Mechanisms of eye injuries from fireworks," *Journal of the American Medical Association*, vol. 308(1), pp. 33-34, 2012.

104. McAllister TW, Flashman LA, Maerlender A, Greenwald RM, Beckwith JG, Tosteson TD, Crisco JJ, Brolinson PG, Duma SM, Duhaime AC, and Grove MR, “Cognitive effects of one season of head impacts in a cohort of collegiate contact sport athletes,” *Neurology*, vol. 78(22), pp. 1777-1784, 2012.

105. Funk JR, Rowson S, Daniel RW, and Duma SM, “Validation of concussion risk curves for collegiate football players derived from HITS data,” *Annals of Biomedical Engineering*, vol. 40(1), pp. 79-89, 2012.

106. Duma SM, Cormier JM, Hurst WJ, Stitzel JD, and Herring IP, "Experimental analysis of airbag seam design: high-rate shear testing for skin abrasions," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 226(4), pp. 468-478, 2012.

107. Crisco JJ, Wilcox BJ, Machan JT, McAllister TW, Duhaime A, Duma SM, Rowson S, Beckwith JG, Chu JJ, and Greenwald RM, "Magnitude of head impact exposures in individual collegiate football players," *Journal of Applied Biomechanics*, vol. 28(2), pp. 174-183, 2012.

108. Duma SM, Bisplinghoff JA, Senge DM, McNally C, and Alphonse VD, "Evaluating the risk of eye injuries: intraocular pressure during high speed projectile impacts," *Current Eye Research*, vol. 37(1), pp. 43-49, 2012.

109. Beyer JA, Rowson S, and Duma SM, "Concussions experienced by major league baseball catchers and umpires: field data and experimental baseball impacts," *Annals of Biomedical Engineering*, vol. 40(1), pp. 150-159, 2012.

110. Rowson S, Duma SM, Beckwith JG, Chu JJ, Greenwald RM, Crisco JJ, Brolinson PG, Duhaime AC, McAllister TW, and Maerlender AC, "Rotational head kinematics in football impacts: an injury risk function for concussion," *Annals of Biomedical Engineering*, vol. 40(1), pp. 1-13, 2012.

111. Gayzik FS, Moreno DP, Danelson KA, McNally C, Klinich KD, Duma SM, Stitzel JD, "External landmark, body surface and volume data of a mid-sized male in seated and standing postures," *Annals of Biomedical Engineering*, vol. 40(9), pp. 2019-2032, 2012.

112. Cantu R, Bishop P, Duma SM, et al, "Helmets," *Journal of Neurosurgery*, 117 (1), 187-189, 2012.

113. Tamura A and Duma SM, "A study on the potential risk of traumatic brain injury due to ground impact in a vehicle-pedestrian collision using full-scale finite element models," *International Journal of Vehicle Safety,* vol. 5(2), pp 117-136, 2011.

114. Beeman SM, Kemper AR, Madigan ML, and Duma SM, "Effects of bracing on human kinematics in low-speed frontal sled tests," *Annals of Biomedical Engineering,* vol. 39(12), pp. 2998-3010, 2011.

115. Crisco JJ, Wilcox BJ, Beckwith JG, Chu JJ, Duhaime AC, Rowson S, Duma SM, Maerlender AC, McAllister TW, and Greenwald RM, "Head impact exposure in collegiate football players," *Journal of Biomechanics*, vol. 44(15), pp. 2673-2678, 2011.

116. Kemper AR, Kennedy EA, McNally C, Manoogian SJ, Stitzel JD, and Duma SM, "Reducing chest injuries in automobile collisions: rib fracture timing and implications for thoracic injury criteria," *Annals of Biomedical Engineering*, vol. 39(8), pp. 2141-2151, 2011.

117. Cormier J, Manoogian S, Bisplinghoff J, Rowson S, Santago A, McNally C, Duma S, and Bolte J, "The Tolerance of the Maxilla to Blunt Impact," *Journal of Biomechanical Engineering*, vol. 133(6), pp. 064501, 2011.

118. Rowson S and Duma SM, "Development of the STAR evaluation system for football helmets: integrating player head impact exposure and risk of concussion," *Annals of Biomedical Engineering*, vol. 39(8), pp. 2130-2140, 2011.

119. Cormier J, Manoogian S, Bisplinghoff J, Rowson S, Santago A, McNally C, Duma SM, and Bolte J, "The tolerance of the frontal bone to blunt impact," *Journal of Biomechanical Engineering*, vol. 133(2), pp. 021004, 2011.

120. Rowson S, Beckwith JG, Chu JJ, Leonard DS, Greenwald RM, and Duma SM, "A six degree of freedom head acceleration measurement device for use in football," *Journal of Applied Biomechanics*, vol. 27(1), pp. 8-14, 2011.

121. Duma SM, Kemper AR, Stitzel JD, McNally C, Kennedy KA, and Matsuoka F, "Rib fracture timing in dynamic belt tests with human cadavers," *Clinical Anatomy*, vol. 24(3), pp. 327-338, 2011.

122. Weaver AA, Loftis KL, Duma SM, and Stitzel JD, "Biomechanical modeling of eye trauma for different orbit anthropometries," *Journal of Biomechanics*, vol. 44(7), pp. 1296-1303, 2011.

123. Weaver AA, Kennedy EA, Duma SM, and Stitzel JD, "Evaluation of different projectiles in matched experimental eye impact simulations," *Journal of Biomechanical Engineering*, vol. 133(3), pp. 031002, 2011.

124. Duma SM and Rowson S, "Past, present, and future of head injury research," *Exercise and Sport Sciences Reviews*, vol. 39(1), pp. 2-3, 2011.

125. Kimpara H, Nakahira Y, Iwamoto M, Rowson S, and Duma SM, "Head injury prediction methods based on 6 degree of freedom head acceleration measurements during impact," *International Journal of Automotive Engineering*, vol. 2(2), pp. 13-19, 2011.

126. Crisco JJ, Fiore R, Beckwith JG, Chu JJ, Brolinson PG, Duma S, McAllister TW, Duhaime AC, and Greenwald RM, "Head impact exposures in individual collegiate football players," *Journal of Athletic Training*, vol. 45(6), pp. 549-559, 2010.

127. Cormier J, Manoogian S, Bisplinghoff J, Rowson S, Santago A, McNally C, Duma SM, and Bolte J, "Biomechanical response of the human face and corresponding biofidelity of the FOCUS headform," *SAE International Journal of Passenger Cars – Mechanical Systems*, vol. 3(2010-01-1317), pp. 842-859, 2010.

128. Kemper AR, Santago AC, Stitzel JD, Sparks JL, and Duma SM, "Biomechanical response of human liver in tensile loading," *Annals of Advances in Automotive Medicine*, vol. 54, pp. 15-26, 2010.

129. Cormier J, Manoogian S, Bisplinghoff J, Rowson, S, Santago A, McNally C, Duma SM, and Bolte J, "The tolerance of the nasal bone to blunt impact," *Annals of Advances in Automotive Medicine*, vol. 54, pp. 3-14, 2010.

130. Rowson S, McNally C, and Duma SM, "Can footwear affect Achilles tendon loading?" *Clinical Journal of Sport Medicine*, vol. 20(5), pp. 344-349, 2010.

131. Shain KS, Madigan ML, Rowson S, Bisplinghoff J, and Duma SM, "Analysis of the ability of catcher's masks to attenuate head accelerations upon impact with a baseball," *Clinical Journal of Sport Medicine*, vol. 20(6), pp. 422-427, 2010.

132. Weaver AA, Loftis KL, Tan JC, Duma SM, and Stitzel JD, "CT based three-dimensional measurement of orbit and eye anthropometry," *Investigative Ophthalmology and Visual Science*, vol. 51(10), pp. 4892-4897, 2010.

133. Bisplinghoff JA, McNally C, Manoogian SJ, and Duma SM, “Dynamic material properties of the human sclera,” *Journal of Biomechanics*, vol. 42(10), pp. 1493-1497, 2009.

134. Manoogian SJ, Bisplinghoff JA, McNally C, Kemper AR, Santago AC, and Duma SM, “Effect of strain rate on the tensile material properties of human placenta,” *Journal of Biomechanical Engineering*, vol. 131(9), pp. 091008, 2009.

135. Rowson S, Brolinson PG, Goforth M, Dietter D, and Duma SM, “Linear and angular head accelerations measurements in collegiate football,” *Journal of Biomechanical Engineering*, vol. 131(6), pp. 061016, 2009.

136. Cormier JM and Duma SM, “The epidemiology of facial fractures in automotive collisions,” *Annals of Advances in Automotive Medicine*, vol. 53, pp. 169-176, 2009.

137. Yu M, Stitzel JD, Duma SM, and Manoogian S, “Finite element modeling of human placental tissue,” *Annals of Advances in Automotive Medicine*, vol. 53, pp. 257-270, 2009.

138. Stitzel J, Danelson K, Gayzik F, Yu M, Martin S, and Duma SM, “Bilateral carotid artery injury response in side impact using a vessel model integrated with a human body model,” *Annals of Advances in Automotive Medicine*, vol. 53, pp. 271-278, 2009.

139. Kemper A, Stitzel J, McNally C, Gabler C, and Duma SM, “Biomechanical response of the human clavicle: the effects of loading direction on bending properties,” *Journal of Applied Biomechanics*, vol. 25(2), pp. 165-174, 2009.

140. Bisplinghoff JA, McNally C, and Duma SM, “High-rate internal pressurization of human eyes to predict globe rupture,” *Archives of Ophthalmology*, vol. 127(4). pp. 520-523, 2009.

141. Gayzik FS, Martin RS, Gabler HC, Hoth JJ, Duma SM, Meredith JW, and Stitzel JD, “Characterization of crash induced thoracic loading resulting in pulmonary contusion,” *Journal of Trauma and Acute Care Surgery*, vol. 66(3), pp. 840-849, 2009.

142. Manoogian SJ, McNally C, Stitzel JD, and Duma SM, “Dynamic biaxial tissue properties of pregnant porcine uterine tissue,” *Stapp Car Crash Journal*, vol. 52, pp. 167, 2008.

143. Manoogian SJ, Bisplinghoff JA, McNally C, Kemper AR, Santago AC, and Duma SM, “Dynamic tensile properties of human placenta,” *Journal of Biomechanics*, vol. 41(16), pp. 3436-3440, 2008.

144. Takhounts EG, Ridella SA, Hasija V, Tannous RE, Campbell JQ, Malone D, Danelson KA, Stitzel JD, Rowson S, and Duma S, "Investigation of traumatic brain injuries using the next generation of simulated injury monitor (SIMon) finite element head model," *Stapp Car Crash Journal*, vol. 52, pp. 1-31, 2008.

145. Kemper AR, McNally C, Kennedy EA, Manoogian SJ, and Duma SM, “The influence of arm position on thoracic response in side impacts,” *Stapp Car Crash Journal*, vol. 52, pp. 379-420, 2008.

146. Rowson S, McNeely DE, Brolinson PG, and Duma SM, “Biomechanical analysis of football neck collars,” *Clinical Journal of Sports Medicine*, vol. 18(4), pp. 316-321, 2008.

147. Kennedy EA and Duma SM, “The effects of the extraocular muscles on eye impact force-deflection and globe rupture response,” *Journal of Biomechanics*, vol. 41(16), pp. 3297-3302, 2008.

148. McGwin G, Modjarrad K, Duma S, Rue LW, "Association between upper extremity injuries and side airbag availability," *Journal of Trauma and Acute Care Surgery*, vol. 64(5), pp. 1297-1301, 2008.

149. Kemper AR, McNally C, Pullins CA, Freeman LJ, Duma SM, and Rouhana SM, "The biomechanics of human ribs: material and structural properties from dynamic tension and bending tests," *Stapp Car Crash Journal*, vol. 51, pp. 235-273, 2007.

150. Kennedy EA, Inzana JA, McNally C, Duma SM, Depinet PJ, Sullenberger KH, Morgan CR, and Brozoski FT, "Development and validation of a synthetic eye and orbit for estimating the potential for Glove Rupture Due to Specific Impact Conditions," *Stapp Car Crash Journal*, vol. 51, pp. 381, 2007.

151. Funk JR, Duma SM, Manoogian SJ, and Rowson S, "Biomechanical risk estimates for mild traumatic brain injury," *Annual Proceedings of the Association for the Advancement of Automotive Medicine*, vol. 51, pp. 343-361, 2007.

152. Kennedy EA, Ng TP, McNally C, Stitzel JD, and Duma SM, "Risk functions for human and porcine eye rupture based on projectile characteristics of blunt objects," *Stapp Car Crash Journal*, vol. 50, pp. 651-671, 2006.

153. Manoogian SJ, Kennedy EA, Wilson KA, Duma SM, and Alem NM, "Predicting neck injuries due to head-supported mass," *Aviation, Space, and Environmental Medicine*, vol. 77(5), pp. 509-514, 2006.

154. Duma S, Moorcroft D, and Stitzel J, "Restraint effectiveness for the pregnant occupant," *Research on Women's Transportation Issues, Journal of the Transportation Research Board*, vol. 54, pp. 1203-1208, 2006.

155. Brolinson PG, Manoogian S, McNeely D, Goforth M, Greenwald R, and Duma S, "Analysis of linear head accelerations from collegiate football impacts," *Current Sports Medicine Reports*, vol. 5(1), pp. 23-28, 2006.

156. Gayzik FS, Bostom O, Ortenwall P, Duma SM, and Stitzel JD, "An experimental and computational study of blunt carotid artery injury," *Annual Proceedings of the Association for the Advancement of Automotive Medicine*, vol. 50, pp. 13-32, 2006.

157. Duma SM, Moorcroft DM, Gabler HC, Manoogian SM, Stitzel JD, and Duma GG, "Analysis of pregnant occupant crash exposure and the potential effectiveness of four-point seatbelts in far side crashes," *Annual Proceedings of the Association for the Advancement of Automotive Medicine*, vol. 50, pp. 177-188, 2006.

158. Kemper AR, McNally C, Kennedy EA, Manoogian SJ, Rath AL, Ng TP, Stitzel JD, Smith EP, Duma SM, and Matsuoka F, "Material properties of human rib cortical bone from dynamic tension coupon testing," *Stapp Car Crash Journal*, vol. 49, pp. 199-230, 2005.

159. Stitzel JD, Gayzik FS, Hoth JJ, Mercier J, Gage HD, Morton KA, Duma SM, and Payne RM, "Development of a finite element-based injury metric for pulmonary contusion part I: model development and validation," *Stapp Car Crash Journal*, vol. 49, pp. 271-289, 2005.

160. Stitzel JD, Hansen GA, Herring IP, and Duma SM, "Blunt trauma of the aging eye: injury mechanisms and increasing lens stiffness," *Archives of Ophthalmology*, vol. 123(6), pp. 789-794, 2005.

161. Duma SM, Ng TP, Kennedy EA, Stitzel JD, and Herring IP, "Determination of significant parameters for eye injury risk from projectiles," *Journal of Trauma***,** vol. 59(4), pp. 960-964, 2005.

162. Rath AL, Manoogian SJ, Duma SM, Bolton BJ, and Crandall JR, *An evaluation of a fiber optic based sensor for measuring chest and abdominal deflection*, SAE Technical Paper 2005-01-0745, 2005.

163. Duma SM, Rath AL, Jernigan MV, Stitzel JD, and Herring IP, "The effects of depowered airbags on eye injuries in frontal automobile crashes," *The American Journal of Emergency Medicine*, vol. 23(1), pp. 13-19, 2005.

164. Jernigan MV, Rath AL, and Duma SM, "Severe upper extremity injuries in frontal automobile crashes: the effects of depowered airbags," *The American Journal of Emergency Medicine*, vol. 23(2), pp. 99-105, 2005.

165. Cormier JM, Stitzel JD, Duma SM, and Matsuoka F, "Regional variation in the structural response and geometrical properties of human ribs," *Annual Proceedings of the Association for the Advancement of Automotive Medicine*, vol. 49, pp. 147-64, 2005.

166. Rath AL, Jernigan MV, Stitzel JD, and Duma SM, "The effects of depowered airbags on skin injuries in frontal automobile crashes," *Plastic and Reconstructive Surgery*, vol. 115(2), pp. 428-435, 2005.

167. Hurst WJ, Cormier JM, Stitzel JD, Jernigan MV, Moorcroft DM, Herring IP, and Duma SM, "A new methodology for investigating airbag-induced skin abrasions," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 219(5), pp. 599-605, 2005.

168. Duma SM, Manoogian SJ, Bussone WR, Brolinson PG, Goforth MW, Donnenwerth JJ, Greenwald RM, Chu JJ, and Crisco JJ, "Analysis of Real-Time Head Accelerations in Collegiate Football Players," *Clinical Journal of Sports Medicine*, vol. 15(1), pp. 3-8, 2005.

169. Jernigan MV, Rath AL, and Duma SM, "Analysis of Burn Injuries in Frontal Automobile Crashes," *Journal of Burn Care and Research*, vol. 25(4), pp. 357-362, 2004.

170. Kennedy E, Hurst W, Stitzel J, Cormier J, Hansen G, Smith E, and Duma S, "Dynamic bending fracture criteria of the human femur for lateral and posterior loading applications," *Stapp Car Crash Journal*, vol. 48, pp. 27-51, 2004.

171. Duma SM, Hansen GA, Kennedy EA, Rath AL, McNally C, Kemper AR, Smith EP, Brolinson PG, and Stitzel JD, "Upper extremity interaction with a helicopter side airbag: injury criteria for dynamic hyperextension of the female elbow joint," *Stapp Car Crash Journal*, vol. 48, pp.155-176, 2004.

172. Stitzel JD, Barretta JT, and Duma SM, "Predicting fractures due to blunt impact: a sensitivity analysis of the effects of altering failure strain of human rib cortical bone," *International Journal of Crashworthiness*, vol. 9(6), pp. 633-642, 2004.

173. Duma SM, Moorcroft DM, Stitzel JD, and Duma GG, "Evaluating pregnant occupant restraints: the effect of local uterine compression on the risk of fetal injury," *Annual Proceedings of the Association for the Advancement of Automotive Medicine*, vol. 48, pp. 103-114, 2004.

174. Jernigan M and Duma S, *Incidence of severe upper extremity injuries and minor skin injuries in frontal automobile crashes*, SAE Technical Paper 2003-01-0513, 2003.

175. Duma S, Jernigan M, and Herring I, *Eye injury and orbital fracture patterns in frontal automobile crashes*, SAE Technical Paper 2003-01-0511, 2003.

176. Duma S, Boggess B, Bass C, and Crandall J, *Injury risk functions for the 5th percentile female upper extremity*, SAE Technical Paper 2003-01-0166, 2003.

177. Moorcroft D, Duma S, Stitzel J, and Duma G, *A finite element and multi-body model of the pregnant female occupant for the analysis of restraint effectiveness*, SAE Technical Paper 2003-01-0157, 2003.

178. Moorcroft D, Stitzel J, Duma S, and Duma G, "The effects of uterine ligaments on the fetal injury risk in frontal automobile crashes," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 217(12), pp. 1049-1055, 2003.

179. Stitzel JD, Cormier JM, Barretta JT, Kennedy EA, Smith EP, Rath AL, Duma SM, and Matsuoka F, "Defining regional variation in the material properties of human rib cortical bone and its effect on fracture prediction," *Stapp Car Crash Journal*, vol. 47, pp. 243-265, 2003.

180. Moorcroft DM, Stitzel JD, Duma GG, and Duma SM, "Computational model of the pregnant occupant: predicting the risk of injury in automobile crashes," *American Journal of Obstetrics and Gynecology*, vol. 189(2), pp. 540-544, 2003.

181. Duma SM and Jernigan MV, "The effects of airbags on orbital fracture patterns in frontal automobile crashes," *Ophthalmic Plastic and Reconstructive Surgery*, vol. 19(2), pp. 107-111, 2003.

182. Hansen GA, Stitzel JD, and Duma SM, "Incidence of elderly eye injuries in automobile crashes: the effects of lens stiffness as a function of age," *Annual Proceedings of the Association for the Advancement of Automotive Medicine*, vol. 47, pp. 147-163, 2003.

183. Duma SM, Crandall JR, Pilkey WD, Seki K, and Aoki T, "Fifth percentile dummy upper extremity interaction with a deploying side air bag," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 217(2), pp. 79-86, 2003.

184. Duma SM, Boggess BM, Crandall JR, and Hurwitz SR, "Upper extremity interaction with a deploying side airbag: a characterization of elbow joint loading," *Accident Analysis and Prevention*, vol. 35(3), pp. 417-425, 2003.

185. Jernigan MV and Duma SM, "The effects of airbag deployment on severe upper extremity injuries in frontal automobile accidents," *The American Journal of Emergency Medicine*, vol. 21(2), pp. 100-105, 2003.

186. Duma SM, Crandall JR, Rudd RW, and Kent RW, "Small female head and neck interaction with a deploying side airbag," *Accident Analysis and Prevention*, vol. 35(5), pp. 811 – 816, 2003.

187. Duma SM, Boggess BM, Crandall JR, and MacMahon CB, "Injury risk function for the small female wrist in axial loading," *Accident Analysis and Prevention*, vol. 35(6), pp. 869-875, 2003.

188. Stitzel J, Duma S, Boggess B, Bass C, and Crandall J, *Frequency content analysis and filter class selection for the small female instrumented upper extremity*, SAE Technical Paper 2002-01-0806, 2002.

189. Power ED, Stitzel JD, Duma SM, Herring IP, and West RL, *Investigation of ocular injuries from high velocity objects in an automobile collision*, SAE Technical Paper 2002-01-0027, 2002.

190. Bass CR, Duma SM, Crandall JR, George S, Kuppa S, Khaewpong N, Sun E, and Eppinger R, "Comparison of upper extremity test devices for the evaluation of frontal air bags," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 216(10), pp. 795-803, 2002.

191. Duma SM, Schreiber PH, McMaster JD, Crandall JR, and Bass CR, "Fracture tolerance of the male forearm: the effect of pronation versus supination," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 216(8), pp. 649-654, 2002.

192. Duma SM, Jernigan MV, Stitzel JD, Herring IP, Crowley JS, Brozoski FT, and Bass CR, "The effect of frontal air bags on eye injury patterns in automobile crashes," *Archives of Ophthalmology*, vol. 120(11), pp. 1517-1522, 2002.

193. Duma SM, Boggess BM, Crandall JR, and Mac Mahon CB, "Fracture tolerance of the small female elbow joint in compression: the effect of load angle relative to the long axis of the forearm," *Stapp Car Crash Journal*, vol. 46, pp. 195-210, 2002.

194. Stitzel JD, Duma SM, Cormier JM, and Herring IP, "A nonlinear finite element model of the eye with experimental validation for the prediction of globe rupture," *Stapp Car Crash Journal*, vol. 46, pp. 81-102, 2002.

195. Power ED, Duma SM, Stitzel JD, Herring IP, West RL, Bass CR, Crowley JS, and Brozoski FT, "Computer modeling of airbag-induced ocular injury in pilots wearing night vision goggles," *Aviation, Space, and Environmental Medicine*, vol. 73(10), pp. 1000-1006, 2002.

196. Duma SM, Stitzel JD, Crandall JR, and Ryan LP, "Determination of bone mineral content in cadaveric test specimens," *Journal of the Southern Orthopedic Association*, vol. 11(2), pp. 80-87, 2002.

197. Jernigan MV, Duma SM, Herring IP, and Stitzel JD, "Analysis of burn injuries in frontal automobile crashes," *Annual Proceedings of the Association for the Advancement of Automotive Medicine*, vol. 46, pp. 413-416, 2002.

198. Kent RW, Crandall JR, Bolton JR, and Duma SM, "Comparison and evaluation of contemporary restraint systems in the driver and front-passenger environments," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 215(11), pp. 1147-1159, 2001.

199. Duma SM, Crandall JR, Seki K, and Aoki T, "Comparison of the Q3 and Hybrid III 3-year-old dummy head and neck response during side air bag loading," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 214(7), pp. 675-684, 2000.

200. Duma SM and Crandall JR, "Eye injuries from airbags with seamless module covers," *Journal of Trauma and Acute Care Surgery*, vol. 48(4), pp. 786-789, 2000.

201. Duma SM, Crandall JR, Hurwitz SR, Pilkey WD, "Small female upper extremity interaction with a deploying side air bag," *Journal of Crash Prevention and Injury Control*, vol. 2(1), pp. 45-61, 2000.

202. Crandall JR., Duma SM, Bass CR, Pilkey WD, Kuppa SM, Khaewpong N, and Eppinger R, "Thoracic response and trauma in air bag deployment tests with out-of-position small female surrogates," *Journal of Crash Prevention and Injury Control*, vol. 1(2), pp. 101-112, 1999.

203. Duma SM, Crandall JR, Pilkey WD, Seki K, and Aoki T, "Dynamic response of the Hybrid III three year old dummy head and neck during side air bag loading," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, vol. 213(5), pp. 471-480, 1999.

204. Duma SM, Schreiber PH, and McMaster JD, Crandall JR, Bass CR, Pilkey WD, "Dynamic injury tolerance for long bones in the female upper extremity," *Journal of Anatomy*, vol. 194(3), pp. 463-471, 1999.

205. Vinger PF, Duma SM, and Crandall JR, "Baseball hardness as a risk factor for eye injuries," *Archives of Ophthalmology*, vol. 117(3), pp. 354-358, 1999.

206. Duma SM, Rudd RW, and Crandall JR, "A protocol system for testing biohazardous materials in an impact biomechanics research facility," *American Industrial Hygiene Association Journal*, vol. 60(5), pp. 629-634, 1999.

207. Duma SM, Rudd RW, and Crandall JR, "The automotive airbag system," *Professional Safety*, vol. 43(10), pp. 24-27, 1998.

208. Crandall JR, Bass CR, Duma SM, and Kuppa SM, *Evaluation of 5th percentile female Hybrid III thoracic biofidelity during out-of-position tests with a driver air bag*, SAE Technical Paper 980636, 1998.

209. Duma SM, Crandall JR, Hurwitz SR, Pilkey WD, "Small female upper extremity interaction with a deploying side air bag," *Stapp Car Crash Journal*, 2695-2711, 1998.

210. Bass CR, Duma SM, Crandall JR, Morris RA, Martin PG, Pilkey WD, Hurwitz SR, Khaewpong N, Eppinger R, and Sun E, *The interaction of air bags with upper extremities*, SAE Technical Paper 973324, 1997.

211. Sieveka EM, Duma SM, Pellettiere J, Crandall JR, Bass CR, and Pilkey WD, *Multi-body model of upper extremity interaction with deploying airbag*, SAE Technical Paper 970398, 1997.

212. Duma SM, Rudd RW, Kress TA, and Porta DJ, *A pneumatic airbag deployment system for experimental testing*, SAE Technical Paper 970124, 1997.

213. Duma SM, Kress TA, Porta DJ, Woods CD, Snider JN, Fuller PM, and Simmons RJ, "Airbag-induced eye injuries: a report of 25 cases," *Journal of Trauma and Acute Care Surgery*, vol. 41(1), pp. 114-119, 1996.

Papers in Refereed Conference Publications (full length manuscripts)

1. Rowson B, Bland ML, Rowson S, Duma SM, "Quantifying head impact duration: analysis of laboratory helmet evaluation systems," *Biomedical Sciences Instrumentation,* 54, 2018.
2. Kemper AR, Beeman SM, Porta DJ, and Duma SM, "Non-censored rib fracture data during frontal PMHS sled testing," *Proceedings of the 60th Annual Scientific Conference of the Association for the Advancement of Automotive Medicine*, Waikoloa, HI, 2016.
3. Beeman SM, Kemper AR, and Duma SM, "Neck forces and moments of human volunteers and post mortem human surrogates in low-speed frontal sled tests," *Proceedings of the 60th Annual Scientific Conference of the Association for the Advancement of Automotive Medicine*, Waikoloa, HI, 2016.
4. Alphonse VD, Kemper AR, and Duma SM, "Effects of filtering on experimental blast overpressure measurements," *Biomedical Sciences Instrumentation*, vol. 51, pp. 143-150, 2015.
5. Alphonse VD, Sajja VS, Kemper AR, Ritzel DV, Duma SM, and VandeVord PJ, "Membrane characteristics for biological blast overpressure testing using blast simulators," *Biomedical Sciences Instrumentation*, vol. 50, pp. 248-53, 2014.
6. Alphonse VD, Kemper AR, and Duma SM, "Blast simulator considerations for biological specimens," *Proceedings of the 40th Annual Northeast Bioengineering Conference*, Boston, MA, 2014.
7. Cobb BR, Rowson S, and Duma SM, "Head impact frequency in youth American football, ages 9-13," *Proceedings of the 32nd International Society of Biomechanics in Sports Conference*, Johnson City, TN, 2014.
8. Young TJ, Rowson S, and Duma SM, "High magnitude head impacts experienced during youth football practices," *Biomedical Sciences Instrumentation*, vol. 50, pp. 100-105, 2014.
9. MacAlister A, Young T, Daniel RW, Rowson S, and Duma SM, "Methodology for mapping football head impact exposure to helmet pads for repeated loading testing," *Biomedical Sciences Instrumentation*, vol. 50, pp. 242-247, 2014.
10. Cobb BR, Rowson S, and Duma SM, "Age-related differences in head impact exposure of 9-13 year old football players," *Biomedical Sciences Instrumentation*, vol. 50, pp. 285-290, 2014.
11. Daniel RW, Rowson S, and Duma SM, "Head acceleration measurements in middle school football," *Biomedical Sciences Instrumentation*, vol. 50, pp. 291-296, 2014.
12. Alphonse VD, Kemper AR, Rowson S, and Duma SM, "Eye injury risk associated with remote control toy helicopter blades," *Biomedical Sciences Instrumentation*, vol. 48, pp. 20-26, 2012.
13. Stitzel JD, Danelson KA, Golman A, Gayzik FS, Kemper A, and Duma SM. "Evaluation of chest injury metrics in human body model and Hybrid III model analyses," *Proceedings of the International Research Council on the Biomechanics of Impact Conference*, Dublin, Ireland, 2012.
14. Kemper AR, Beeman SM, and Duma SM, "Effects of pre-impact bracing on chest compression of human occupants in low speed frontal sled tests," *Proceedings of the 22nd Enhanced Safety of Vehicles Conference*, no. 11-0193, Washington, DC, 2011.

15. Kemper AR, Santago AC, Sparks JL, Stitzel JD, and Duma SM, "Multi-scale biomechanical characterization of human liver and spleen," *Proceedings of the 22nd Enhanced Safety of Vehicles Conference*, no. 11-0195, Washington, DC, 2011.

16. Takhounts EG, Hasija V, Ridella SA, Rowson S, and Duma SM, "Kinematic rotational brain injury criterion (BRIC)," *Proceedings of the 22nd Enhanced Safety of Vehicles Conference*, no. 11-0263-0, Washington, DC, 2011.

17. Kimpara H, Nakahira Y, Iwamoto M, Rowson S, and Duma S, "Head injury prediction methods based on 6 degree of freedom head acceleration measurements during impact," *Society of Automotive Engineers of Japan*, no. 20105118, 2010.

18. Duma SM and Rowson S, "Every Newton hertz: a macro to micro approach to investigating brain injury," *Proceedings of the 31st International Conference of the IEEE Engineering in Medicine and Biology Society*, pp. 1123-6, 2009.

19. Kemper AR and Duma SM, "Development of response corridors for the compressive stiffness of the male and female upper arm in lateral loading," *Proceedings of the 21st Enhanced Safety of Vehicles Conference*, no. 09-0506, Stuttgart, Germany, 2009.

20. Kemper A, McNally C, and Duma SM, "Load transfer and deformation characteristics of the pelvis in non-destructive side impact testing," *Proceedings of the 21st Enhanced Safety of Vehicles Conference*, no. 09-0508 Stuttgart, Germany, 2009.

21. Santago AC, Kemper AR, McNally C, Sparks JL, and Duma SM, "The effect of temperature on the mechanical properties of bovine liver," *Biomedical Sciences Instrumentation*, vol. 45, pp. 376-381, 2009.

22. Santago AC, Kemper AR, McNally C, Sparks JL, and Duma SM, "Freezing affects the mechanical properties of bovine liver," *Biomedical Sciences Instrumentation*, vol. 45, pp. 24-29, 2009.

23. Bisplinghoff JA and Duma SM, "The effect of stress and strain formulations on the representation of biological tissue mechanical properties," *Biomedical Sciences Instrumentation*, vol. 45 pp. 389-394, 2009.

24. Bisplinghoff JA and Duma SM, "Evaluation of eye injury risk from projectile shooting toys using the FOCUS headform," *Biomedical Sciences Instrumentation*, vol. 45, pp. 107-112, 2009.

25. Rowson S, McNally C, and Duma SM, "In situ measurement of Achilles tendon tension during dorsiflexion," *Biomedical Sciences Instrumentation*, vol. 45, pp. 18-23, 2009.

26. Rowson S, Goforth MW, Dietter D, Brolinson PG, and Duma SM, "Correlating cumulative sub-concussive head impacts in football with player performance," *Biomedical Sciences Instrumentation*, vol. 45, pp. 113-118, 2009.

27. Kemper AR, McNally C, and Duma SM, "The effect of the periosteum and strain gages on the structural response of human ribs," *Biomedical Sciences Instrumentation*, vol. 45, pp. 12-17, 2009.

28. Kemper AR, McNally C, and Duma SM, "Acquiring non-censored pelvic bone fracture data during dynamic side impact loading," *Biomedical Sciences Instrumentation*, vol. 45, pp. 395-400, 2009.

29. Danelson KA, Gayzik FS, Yu MM, Duma SM, and Stitzel JD, *A regional finite element model of the neck for bilateral carotid artery injury assessment in far side crash configuration*, SAE Technical Paper 2009-01-2265, 2009.

30. Gayzik FS, Hamilton CA, Tan JC, McNally C, Duma SM, Klinich KD, and Stitzel JD, *A multi-modality image data collection protocol for full body finite element model development*, SAE Technical Paper 2009-01-2261, 2009.

31. Rowson S, McNeely DE, and Duma SM, "Force transmission to the mandible by chin straps during head impacts in football," *Biomedical Sciences Instrumentation*, vol. 44, pp. 195-200, 2008.

32. Rowson S, McNeely DE, and Duma SM, "Differences in Hybrid III and THOR-NT neck response in extension using matched tests with football neck collars," *Biomedical Sciences Instrumentation*, vol. 44, pp. 165-170, 2008.

33. Kennedy EA, Stitzel, JD, and Duma SM, "Matched experimental and computational simulations of paintball eye impacts," *Biomedical Sciences Instrumentation*, vol. 44, pp. 243-248, 2008.

34. Manoogian SJ, Duma SM, and Moorcroft DM, "Evaluation of pregnant female injury risk during everyday activities," *Biomedical Sciences Instrumentation*, vol. 44, pp. 183-188, 2008.

35. Manoogian SJ, Moorcroft DM, and Duma SM, "Pregnant occupant injury risk in severe frontal crashes using computer simulations," *Biomedical Sciences Instrumentation*, vol. 44, pp. 249-255, 2008.

36. Kemper AR, McNally C, and Duma SM, "Dynamic tensile material properties of human pelvic cortical bone," *Biomedical Sciences Instrumentation*, vol. 44, pp. 417-422, 2008.

37. Kemper AR, McNally C, Manoogian SJ, and Duma SM, "Tensile material properties of human tibia cortical bone: effects of orientation and loading rate," *Biomedical Sciences Instrumentation*, vol. 44, pp. 419-427, 2008.

38. Kemper AR, McNally C, and Duma SM, "Biofidelity of an original and modified SID-IIs upper extremity: matched cadaver and dummy compression tests," *Biomedical Sciences Instrumentation*, vol. 44, pp. 111-116, 2008.

39. Kemper AR, McNally C, and Duma SM, "Dynamic compressive response of the human pelvis: axial loading of the sacroiliac joint," *Biomedical Sciences Instrumentation*, vol. 44, pp. 171-176, 2008.

40. Santago AC, Cormier JM, Duma SM, Yoganandan N, and Pintar FA, "Forearm fracture bending risk function for the 50th percentile male," *Biomedical Sciences Instrumentation*, vol. 44, pp. 201-206, 2008.

41. Santago AC, Cormier JM, and Duma SM, "Humerus fracture bending risk function for the 50th percentile male," *Biomedical Sciences Instrumentation*, vol. 44, pp. 231-236, 2008.

42. Bisplinghoff JA, McNally C, Yang S, Herring IP, Brozoski FT, and Duma SM, "High rate internal pressurization of the human eye to determine dynamic rupture pressure," *Biomedical Sciences Instrumentation*, vol. 44, pp. 117-122, 2008.

43. Bisplinghoff JA, McNally C, Brozoski FT, and Duma SM, “Dynamic material property measurements of human eyes,” *Biomedical Sciences Instrumentation*, vol. 44, pp. 177-182, 2008.

44. Duma SM, Kemper AR, and Porta DJ, “Biomechanical response of the human cervical spine,” *Biomedical Sciences Instrumentation*, vol. 44, pp. 135-140, 2008.

45. Cormier J, Manoogian S, Bisplinghoff J, McNally C, and Duma S, “The use of acoustic emission in facial fracture detection,” *Biomedical Sciences Instrumentation*, vol. 44, pp. 147-152, 2008.

46. Loftis K, Halsey M, Anthony E, Duma SM, and Stitzel J, “Pregnant female anthropometry from CT scans for finite element model development,” *Biomedical Sciences Instrumentation*, vol. 44, pp. 355-360, 2008.

47. Rowson S, McNeely DE, and Duma SM, "Lateral bending biomechanical analysis of neck protection devices used in football," *Biomedical Sciences Instrumentation*, vol. 43, pp. 200-205, 2007.

48. Kemper A, McNally C, Manoogian S, McNeely D, and Duma S, “Stiffness properties of human lumbar intervertebral discs in compression and the influence of strain rate,” *Proceedings of the 20th Enhanced Safety of Vehicles Conference*, no. 07-0471, Lyon, France, 2007.

49. Kemper A, McNally C, Kennedy E, Manoogian S, and Duma S, “The material properties of human tibia cortical bone in tension and compression: implications for the tibia index,” *Proceedings of the 20th Enhanced Safety of Vehicles Conference*, no. 07-0470, Lyon, France, 2007.

50. Manoogian SJ, Duma SM, and Moorcroft DM, “Pregnant occupant injury risk using computer simulations with NCAP vehicle crash test data,” *Proceedings of the 20th Enhanced Safety of Vehicles Conference*, no. 07-0168, Lyon, France, 2007.

51. Kennedy EA, McNally C, and Duma S, “Experimental techniques for measuring the biomechanical response of the eye during impact,” *Biomedical Sciences Instrumentation*, vol. 43, pp. 7-12, 2007.

52. Kemper AR, McNally C, and Duma SM, “The influence of strain rate on the compressive stiffness properties of human lumbar intervertebral discs,” *Biomedical Sciences Instrumentation*, vol. 43, pp. 176-181, 2007.

53. Manoogian S, McNally C, Calloway B, and Duma S, “Methodology for dynamic biaxial tension testing of pregnant uterine tissue,” *Biomedical Sciences Instrumentation*, vol. 43, pp. 230-235, 2007.

54. Kemper AR, McNally C, Smith B, and Duma SM, “Quasi-linear viscoelastic characterization of human hip ligaments,” *Biomedical Sciences Instrumentation*, vol. 43, pp. 324-329, 2007.

55. Kennedy EA, Tordonado DS, and Duma SM, “Effects of freezing on the mechanical properties of articular cartilage,” *Biomedical Sciences Instrumentation*, vol. 43, pp. 342-347, 2007.

56. Manoogian S, McNally C, Calloway B, Duma S, and Mertz H, “Utilizing cryogenic grips for dynamic tension testing of human placenta tissue,” *Biomedical Sciences Instrumentation*, vol. 43, pp. 354-359, 2007.

57. Kennedy EA, Duma SM, Depinet P, Morgan C, Beebe M, Roller R, Crowley J, and Brozoski F, "Design of an advanced headform for the prediction of eye and facial injuries," *Proceedings of the 25th Army Science Conference*, Orlando, FL, 2006.

58. Duma SM, Hansen GA, Kennedy EA, Stitzel JD, Brozoski FT, and Crowley J, "Injury criteria for dynamic hyperextension of the female elbow joint," *Proceedings of the 25th Army Science Conference*, Orlando, FL, 2006.

59. McGwin G and Duma S, "Association between upper extremity injuries and side airbag availabiltiy," *Proceedings of the 50th Annual Scientific Conference of the Association for the Advancement of Automotive Medicine*, Chicago, IL, 2006.

60. Ng TP, Bussone WR, Duma SM, and Kress TA, "Thoracic and lumbar spine accelerations in everyday activities," *Biomedical Sciences Instrumentation*, vol. 42, pp. 410-415, 2006.

61. Kennedy EA, Ng TP, and Duma SM, "Evaluating eye injury risk of airsoft pellet guns by parametric risk functions," *Biomedical Sciences Instrumentation*, vol. 42, pp. 7-12, 2006.

62. Manoogian SJ, Kennedy EA, Wilson K, and Duma SM, "Prevention of facial fractures from night vision goggle impact," *Biomedical Sciences Instrumentation*, vol. 42, pp. 13-18, 2006.

63. Ng TP, Bussone WR, and Duma SM, "The effect of gender and body size on linear accelerations of the head observed during daily activities," *Biomedical Sciences Instrumentation*, vol. 42, pp. 25-30, 2006.

64. Daly M, Duma SM, and Stitzel JD, "Retrospective identification of subject anthropometry using computed tomography of the leg," *Biomedical Sciences Instrumentation*, vol. 42, pp. 114-119, 2006.

65. Cormier JM, Stitzel JD, Hurst WJ, Porta DJ, Jones J, and Duma SM, "Predicting zygoma fractures from baseball impact," *Biomedical Sciences Instrumentation*, vol. 42, pp. 142-147, 2006.

66. Duma SM, Stitzel JD, Kemper AR, McNally C, Kennedy EA, Brolinson PG, and Matsuoka F, "Acquiring non-censored rib fracture data during dynamic belt loading," *Biomedical Sciences Instrumentation*, vol. 42, pp. 148-153, 2006.

67. Gayzik FS, Tan JC, Duma SM, and Stitzel JD, "Mesh development for a finite element model of the carotid artery," *Biomedical Sciences Instrumentation*, vol. 42, pp. 187-192, 2006.

68. Kemper AR, Stitzel JD, Gabler HC, Duma SM, and Matsuoka F, "Biomechanical response of the human clavicle subjected to dynamic bending," *Biomedical Sciences Instrumentation*, vol. 42, pp. 231-236, 2006.

69. Kemper AR, Ng TP, and Duma SM, "The biomechanical response of human bone: the influence of bone volume and mineral density," *Biomedical Sciences Instrumentation*, vol. 42, pp. 284-289, 2006.

70. Kennedy EA, Bonivtch AR, Manoogian SJ, Stitzel JD, Herring IP, and Duma SM, "The effects of extraocular muscles on static displacements of the human eye," *Biomedical Sciences Instrumentation*, vol. 42, pp. 372-377, 2006.

71. Manoogian S, McNeely D, Goforth M, Brolinson G, and Duma S, "Head acceleration is less than 10 percent of helmet acceleration during a football impact," *Biomedical Sciences Instrumentation*, vol. 42, pp. 383-388, 2006.

72. Duma SM, Kemper AR, McNeely DM, Brolinson PG, and Matsuoka F, "Biomechanical response of the lumbar spine in dynamic compression," *Biomedical Sciences Instrumentation*, vol. 42, pp. 476-481, 2006.

73. Duma SM, Moorcroft DM, Stitzel JD, and Duma GG, "Biomechanical modeling of pregnant occupants in far-side vehicle crashes," *Biomedical Sciences Instrumentation*, vol. 42, pp. 154-159, 2006.

74. Duma S, Stitzel J, Kemper A, McNally C, Kennedy E, and Matsuoka F, "Non-censored rib fracture data from dynamic belt loading tests on the human cadaver thorax," *Proceedings of the 19th Enhanced Safety of Vehicles Conference*, no. 05-0360, Washington, DC, 2005.

75. Kemper A, Stitzel J, Duma S, Matsuoka F, and Masuda M, "Biofidelity of the SID-IIs and a modified SID-IIs upper extremity: biomechanical properties of the human humerus," *Proceedings of the 19th Enhanced Safety of Vehicles Conference*, no. 05-0123, Washington, DC, 2005.

76. Duma SM, Moorcroft D, Stitzel J, and Duma G, "A computational model of the pregnant occupant: effects of restraint usage and occupant position on fetal injury risk," *Proceedings of the 19th Enhanced Safety of Vehicles Conference*, no. 05-0367, Washington, DC, 2005.

77. Fildes B, Linder A, Douglas C, Digges K, Morgan R, Pintar F, Yoganandan N, Gabler H, Duma S, Stitzel J, Bostrom O, Sparke L, Smith S, and Newland C, "Occupant protection in far side crashes," *Proceedings of the 19th Enhanced Safety of Vehicles Conference*, no. 05-0299, Washington, DC, 2005.

78. Rath AL, Manoogian SJ, Duma SM, Bolton BJ, and Crandall JR, *An evaluation of a fiber optic based sensor for measuring chest and abdominal deflection*, SAE Technical Paper 2005-01-0745, 2005.

79. Duma S, Stitzel J, Rath A, Kennedy E, Cotton J, and Funk J, "Using three-point bending tests to generate biomechanical data: an analysis of measured structural response versus derived material properties," *SAE World Congress and Exhibition*, Detroit, MI, 2005.

80. Duma SM, Moorcroft D, Stitzel J, and Duma G, "Computational model of pregnant motor vehicle occupant," *Research on Women's Issues in Transportation*, pp. 141-147, 2004.

81. Duma S, Tordonato D, Hansen G, Stitzel J, and Kennedy E, "The effects of freezing on the mechanical properties of articular cartilage," *Proceedings of the International Research Council on the Biomechanics of Impact Conference*, Graz, Austria, 2004.

82. Stitzel J, Duma S, Iwamoto M, Tamura A, "Rib fracture prediction using finite element modeling: a sensitivity analysis of the effects of failure strain selection," *Proceedings of the International Research Council on the Biomechanics of Impact Conference*, Graz, Austria, 2004.

83. Kennedy EA, Voorhies KD, Herring IP, Rath AL, and Duma SM, "Prediction of severe eye injuries in automobile accidents: static and dynamic rupture pressure of the eye," *Proceedings*

of the 48th Annual Scientific Conference of the Association for the Advancement of Automotive Medicine, Key Biscayne, FL, 2004.

84. Duma S and Rath A, "An analysis of AAAM abstract submission acceptance rates," *Proceedings of the 48th Annual Scientific Conference of the Association for the Advancement of Automotive Medicine*, Key Biscayne, FL, 2004.

85. Moorcroft DM, Stitzel JD, Duma SM, and Duma GG, *The effect of pregnant occupant position and belt placement on the risk of fetal injury*, SAE Technical Paper 2004-01-0324, 2004.

86. Duma SM, Cormier JM, Hurst WJ, Stitzel JD, and Herring IP, "The effects of seam design on airbag induced skin abrasions from high-rate shear loading," *Proceedings of the International Research Council on the Biomechanics of Impact Conference*, Lisbon, Portugal, 2003.

87. Jernigan MV and Duma SM, "The effects of depowered airbags on severe upper extremity injuries in frontal automobile crashes," *Proceedings of the 47th Annual Scientific Conference of the Association for the Advancement of Automotive Medicine*, Lisbon, Portugal, 2003.

88. Moorcroft D, Duma S, Stitzel J, and Duma G, *A finite element and multi-body model of the pregnant female occupant for the analysis of restraint effectiveness*, SAE Technical Paper 2003-01-0157, 2003.

89. Duma S, Boggess B, Bass C, and Crandall J, "Injury risk functions for the 5th percentile female upper extremity," SAE Technical Paper 2003-01-0166, 2003.

90. Jernigan M and Duma S, *Incidence of severe upper extremity injuries and minor skin injuries in frontal automobile crashes*, SAE Technical Paper 2003-01-0513, 2003.

91. Duma S, Jernigan M, and Herring I, *Eye injury and orbital fracture patterns in frontal automobile crashes*, SAE Technical Paper 2003-01-0511, 2003.

92. Duma SM, Jernigan MV, Stitzel JD, and Herring IP, "Eye injury incidence and mechanisms in frontal automobile crashes," *Proceedings of the 18th Enhanced Safety of Vehicles Conference*, no. 82, Nagoya, Japan, 2003.

93. Moorcroft DM, Jernigan M, Duma SM, and Duma GG, "A finite element model of the pregnant female occupant: analysis of injury mechanisms and restraint systems," *Proceedings of the 46th Annual Scientific Conference of the Association for the Advancement of Automotive Medicine*, Tempe, AZ, 2002.

94. Jernigan M, Duma SM, Herring IP, and Stitzel JD, "Analysis of burn injuries in frontal automobile crashes," *Proceedings of the 46th Annual Scientific Conference of the Association for the Advancement of Automotive Medicine*, Tempe, AZ, October, 2002.

95. Stitzel J, Duma S, Boggess B, Bass C, and Crandall J, *Frequency content analysis and filter class selection for the small female instrumented upper extremity*, SAE Technical Paper 2002-01-0806, 2002.

96. Power ED, Stitzel JD, Duma SM, Herring IP, and West RL, *Investigation of ocular injuries from high velocity objects in an automobile collision*, SAE Technical Paper 2002-01-0027, 2002.

97. Jernigan M., Duma SM, Herring I, Stitzel JD, Bass CR, Crowley JS, Brozoski FT, "Eye injury patterns in automobile crashes: the effect of frontal airbags," *Proceedings of the 45th Annual*

Scientific Conference of the Association for the Advancement of Automotive Medicine, San Antonio, TX, 2001.

98. Boggess BM, Sieveka EM, Crandall JR, Pilkey WD, and Duma SM, *Interaction of the hand and wrist with a door handgrip during static side air bag deployment: simulation study using the CVS/ATB multi-body program*, SAE Technical Paper 2001-01-0170, 2001.

99. Duma SM, Boggess BM, Crandall JR, Hurwitz SR, Seki K, and Aoki T, "Analysis of Upper Extremity Response Under Side Airbag Loading," *Proceedings of the 17th Enhanced Safety of Vehicles Conference*, no. 195, Amsterdam, Netherlands, 2001.

100. Kent RW, Crandall JR, Bolton JR, and Duma SM, "Driver and right-front passenger restraint system interaction, injury potential, and thoracic injury prediction," *Proceedings of the 44th Annual Scientific Conference of the Association for the Advancement of Automotive Medicine*, Chicago, IL, 2000.

101. Duma SM, Crandall JR, and Pilkey WD, "Comparison of the Q3 and hybrid III three-year-old dummy head and neck response during side air bag loading," *Proceedings of the 1st Child Occupant Protection in Motor Vehicle Crashes Conference*, Barcelona, Spain, 1999.

102. Duma SM, Crandall JR, Rudd RW, Funk JR, and Pilkey WD, "Small female head and neck interaction with a deploying side air bag," *Proceedings of the International Research Council on the Biomechanics of Impact Conference*, Sitges, Spain, 1999.

103. Duma SM and Crandall JR, "Eye injuries from air bags with seamless module covers," *Proceedings of the 43th Annual Scientific Conference of the Association for the Advancement of Automotive Medicine*, Barcelona, Spain, 1999.

104. Sieveka E, Crandall J, Duma S, and Pilkey W, *Three year old child and side airbag interaction study using the CVS/ATB multi-body simulation program*, SAE Technical Paper 1999-01-0756, 1999.

105. Duma SM, Crandall JR, Hurwitz SR, and Pilkey WD, *Small female upper extremity interaction with a deploying side air bag*, SAE Technical Paper 983148, 1998.

106. Crandall JR, Bass CR, Duma SM, and Kuppa SM, *Evaluation of 5th percentile female Hybrid III thoracic biofidelity during out-of-position tests with a driver air bag*, SAE Technical Paper 980636, 1998.

107. Duma SM, Kress TA, Porta DJ, Martin PG, Simmons RJ, and Alexander CL, "An experimental study of airbag impact to the orbit using an instrumented Hybrid III headform," *Biomedical Sciences Instrumentation*, vol. 33, pp. 59-64, 1997.

108. Duma SM, Bass CR, Klopp GS, Grillo NR, Micek TJ, Crandall JR, and Pilkey WD, "A technique for using strain gauges to evaluate airbag interaction with cadaveric upper extremities," *Biomedical Sciences Instrumentation*, vol. 33, pp. 47-52, 1997.

109. Duma SM, Kress TA, Porta DJ, Simmons RJ, Alexander CL, and Woods CD, "Airbag-induced eye injuries: experiments with in situ cadaver eyes," *Biomedical Sciences Instrumentation*, vol. 33, pp. 106-111 1997.

110. Sieveka EM, Duma SM, Pellettiere J, Crandall JR, Bass CR, and Pilkey WD, *Multi-body model of upper extremity interaction with deploying airbag*, SAE Technical Paper 970398, 1997.

111. Duma SM, Crandall JR, Pilkey WD, Seki K, and Aoki T, "5th % female dummy upper extremity interaction with a deploying side airbag," *Proceedings of the 16th Enhanced Safety of Vehicles Conference*, no. 98-S5-W-20 Windsor, Canada, 1998.

112. Bass CR, Duma, SM, Crandall JR, George SK, Kuppa S, Khaewpong N, Sun E, and Eppinger RH, "The interaction of airbags with upper extremity test devices," *Proceedings of the 16th Enhanced Safety of Vehicles Conference*, no. 98-S7-O-12 Windsor, Canada, 1998.

113. Sieveka EM, Crandall JR, Duma SM, and Pilkey WD, "Development and application of a side airbag computer model using the CVS/ATB multi-body dynamics program," *Proceedings of the 16th Enhanced Safety of Vehicles Conference*, no. 98-S9-O-05, Windsor, Canada, 1998.

114. Duma SM, Schreiber PH, McMaster JD, Crandall JR, Bass CR, and Pilkey WD, "Dynamic Injury Tolerances for Long Bones of the Female Upper Extremity," *Proceedings of the International Research Council on the Biomechanics of Impact Conference*, Gothenburg, Sweden, 1998.

115. Duma SM, Crandall JR, Pilkey WD, Seki K, and Aoki T, "Dynamic response of the Hybrid III 3 year old dummy head and neck during side air bag loading," *Proceedings of the 42nd Annual Scientific Conference of the Association for the Advancement of Automotive Medicine*, Charlottesville, VA, 1998.

OTHER CONFERENCE PAPERS (TWO-PAGE ABSTRACT STYLE OR SHORT STUDY)

1. LA Duma, M Begonia, B Miller, SM Duma, Proposed injury metric for drone blade design. Biomedical Engineering Society Annual Conference, virtual, 2020.
2. BG Duma, M Begonia, SM Duma, Relationship between linear and rotational accelerations in watersport helmet testing. Biomedical Engineering Society Annual Conference, virtual, 2020.
3. E. Campolettano, E. Smith, R. Gellner, A. Maerlender, M. Kelley, D. Jones, J. Urban, J. Stitzel, S. Bellamkonda, C. Tierney, J. Crisco, A. Ajamal, J. Beckwith, R. Greenwald, G. Brolinson, S. Duma, S. Rowson, Development of a Concussion Risk Function for a Youth Population Using Head Linear and Rotational Acceleration, Biomedical Engineering Society Annual Meeting, Philadelphia PA, 2019.
4. B. Stemper, A. Shah, L. Riggen, S. Rowson, J. Mihalik, S. Duma, T. McAllister, S. Broglio, M. McCrea, Correlation of Concussion Timing with Head Impact Exposure in College Football, Biomedical Engineering Society Annual Meeting, Philadelphia PA, 2019.
5. L. Duma, A. Bhandare, T. Canfield, Z. Davis, M. Begonia, B. Miller, S. Duma, Experimental Analysis of Skin and Eye Surrogate Models for Drone Blade Lacerations, Biomedical Engineering Society Annual Meeting, Philadelphia PA, 2019.
6. B. Duma, M. Begonia, A. Tyson, C. Charron, S. Rowson, S. Duma, Watersport Helmet STAR: Summation Of The Biomechanical Performance And Risk Of Injury, Biomedical Engineering Society Annual Meeting, Philadelphia PA, 2019.
7. B. Duma, A. Tyson, C. Charron, S. Duma, Analysis of watersport helmets ability to reduce head impact accelerations, Summer Biomechanics, Bioengineering, and Biotransport Conference, Silver Springs, PA, 2019

8. L. Duma, A. Bhandare, T. Canfield, Z. Davis, M. Begonia, B. Miller, S. Duma, Drone blade induced skin laceration and eye injury risk; an investigation of skin and eye surrogate models, Summer Biomechanics, Bioengineering, and Biotransport Conference, Silver Springs, PA, 2019.
9. Giza C, Huber D, Gill J, McArthur D, McAllister T, Broglio S, Meier T, McGinty G, Cameron K, Houston M, Jackson J, Guskiewicz K, Mihalik J, Brooks A, Duma S, Rowson S, Pasquina P, and McCrea M, "Acute biomarkers in military cadets sustaining concussions outside of varsity sports participation," Military Health System Research Symposium, 2019.
10. McCrea M, Huber D, Gill J, Giza C, McAllister T, Broglio S, Meier T, Cameron K, Houston M, McGinty G, Jackson J, Guskiewicz K, Mihalik J, Brooks A, Duma S, Rowson S, and Pasquina P, "Blood biomarkers in acute sport-related concussion: findings from the NCAA-DoD CARE Consortium study," Military Health System Research Symposium, 2019.
11. Stemper BD, Shah AS, Rowson S, Duma S, Harezlak J, Mihalik J, Riggen L, Cameron K, Houston M, Jackson J, McGinty G, Broglio S, McAllister T, and McCrea M, "Changes in preseason head impact exposure for football athletes at the military service academies following 2017 and 2018 NCAA rule changes," Military Health System Research Symposium, 2019.
12. Stemper B, Shah A, Rowson S, Duma S, Mihalik J, Harezlak J, Riggen L, Broglio S, McAllister T, and McCrea M, "Comparison of head impact exposure between concussed and non-concussed football athletes," Biomedical Engineering Society Scientific Meeting, Atlanta, GA, 2018.
13. Stemper B, Shah A, Rowson S, Duma S, Mihalik J, Harezlak J, Riggen L, Broglio S, McAllister T, and McCrea M, "Comparison of head impact exposure between concussed and non-concussed football athletes," Biomedical Engineering Society Scientific Meeting, Atlanta, GA, 2018.
14. Stemper BD, Shah AS, Rowson S, Duma S, Harezlak J, Mihalik J, Riggen L, Cameron K, Campbell D, Jackson J, McGinty G, Svoboda S, Broglio S, McAllister T, and McCrea M, "Mechanisms of concussion in football athletes at the military service academies: single impact versus repetitive head impact exposure," Military Health System Research Symposium, Kissimmee FL, 2018.
15. Campolettano E, Rowson S, Duma S, Stemper B, Shah A, Mihalik J, Harezlak J, McAllister T, Broglio S, and McCrea M, "Factors affecting head impact exposure in college football practices: a multi-institutional study," World Congress of Biomechanics, Dublin Ireland, 2018.
16. Tyson A and Rowson S, "Effects of stiffness and thickness on soccer head gear performance," World Congress of Biomechanics, Dublin Ireland, 2018.
17. Stemper B, Shah A, Rowson S, Duma S, Mihalik J, Jarezlak J, McAllister T, Broglio S, and McCrea M, "Characteristics of head impact exposure in concussed and non-concussed college American football athletes," World Congress of Biomechanics, Dublin Ireland, 2018.
18. Duma S and Rowson S, "Brains, strains, and automobiles: concussion biomechanics and instrumentation," World Congress of Biomechanics, Dublin Ireland, 2018.

19. Campolettano E, Bland M, Gellner R, Sproule D, Rowson B, Tyson A, Duma S, and Rowson S, "Ranges of injury risk associated with impact from unmanned aircraft," World Congress of Biomechanics, Dublin Ireland, 2018.
20. Swaak A, Tyson AM, Duma SM, "Analysis of equestrian helmet impact response in ASTM certification tests," World Congress of Biomechanics, Dublin Ireland, 2018.
21. Swaak A, Tyson AM, Duma SM, "Polo helmet impact response in NOCSAE and ASTM standard testing methods," World Congress of Biomechanics, Dublin Ireland, 2018.
22. Duma BG, Tyson AM, Charron CL, Duma SM, "Analysis of watersport helmets ability to reduce head impact accelerations," Biomedical Engineering Society Scientific Meeting, Atlanta, GA, 2018.
23. Campolettano E, Bland M, Gellner R, Sproule D, Rowson B, Tyson A, Duma S, and Rowson S, "Quantifying the range of injury risk to the head and neck from unmanned aircraft systems," Biomedical Engineering Society Scientific Meeting, Phoenix, AZ, 2017.
24. Rowson B, Rowson S, and Duma S, "Assessing brain injury criteria through reconstructions of head impacts in football," Biomedical Engineering Society Scientific Meeting, Phoenix, AZ, 2017.
25. Rowson B, Rowson S, and Duma S, "Characterizing brain injury criteria for concussion through reconstructions of collegiate
26. Rowson B, Rowson S, and Duma SM, "Evaluating the ability of head injury criteria to predict concussion through reconstructions of collegiate football head impacts," *National Neurotrauma Society Symposium*, Snowbird, UT, 2017.
27. Sanchez E, Gabler L, Rowson B, Rowson S, Duma S, and Panzer MB, "Brain strain patterns associated with football impact reconstructions," *National Neurotrauma Society Symposium*, Snowbird, UT, 2017.
28. Albert DL, Beeman SM, McNally C, and Kemper AR, "Effect of restraint conditions and ATD type on thoracic and femoral responses in frontal sled tests," *Biomedical Engineering Society Annual Meeting*, Minneapolis, MN, 2016.
29. Rowson B, Tyson AM, Cobb BR, Rowson S, and Duma SM, "Biomechanical performance of hockey helmets," *Biomedical Engineering Society Annual Meeting*, Minneapolis, MN, 2016.
30. Campolettano E, Rowson S, and Duma S, "Drill-specific head impact exposure in youth football practice," *Biomedical Engineering Society Annual Meeting*, Minneapolis, MN, 2016.
31. Rowson B, Rowson S, and Duma S, "Assessing the ability of hockey helmets to reduce concussion risk," *Summer Biomechanics, Bioengineering, and Biotransport Conference*, National Harbor, 2016.
32. Campolettano E, Rowson S, and Duma S, "Drill-specific head impact exposure in youth football practice," *Summer Biomechanics, Bioengineering, and Biotransport Conference*, National Harbor, 2016.
33. Tyson A, Rowson S, and Duma S, "Laboratory evaluation of head impact sensors," *Summer Biomechanics, Bioengineering, and Biotransport Conference*, National Harbor, 2016.

34. Rowson B, Tyson AM, Cobb BR, Rowson S, and Duma SM, "Assessing the relative impact performance of hockey helmets," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Winston-Salem, NC, 2016.

35. Kemper AR, Beeman SM, and Duma SM, "Quantification of rib fracture timing during frontal sled tests," *Biomedical Engineering Society Annual Meeting*, Tampa, FL, 2015.

36. Beeman SM, Kemper AR, and Duma SM, "Human volunteer neck forces and moments during low-speed frontal sled tests," *Biomedical Engineering Society Annual Meeting*, Tampa, FL, 2015.

37. Alphonse VD, Kemper AR, and Duma SM, "Eye and face response to blast overpressure: an experimental study using a 3D-printed human face," *Biomedical Engineering Society Annual Meeting*, Tampa, FL, 2015.

38. Tyson A, Cobb B, Rowson S, and Duma S, "Comparing the ability of head impact sensors to measure head kinematics," *Biomedical Engineering Society Annual Meeting*, Tampa, FL, 2015.

39. Rowson B, Rowson S, and Duma S, "Development of a methodology for assessing the biomechanical performance of hockey helmets," *Biomedical Engineering Society Annual Meeting*, Tampa, FL, 2015.

40. Beeman SM, Rowson S, and Duma SM, "Head impact response resulting from forceful impact with toy swords by pediatric males," *Summer Biomechanics, Bioengineering, and Biotransport Conference*, Snowbird, UT, 2015.

41. Rowson B, Rowson S, and Duma SM, "Effect of neck cable tension during helmeted head impact," SB3C, Snowbird, UT, 2015.

42. Zadnik AM, Rowson S, and Duma SM, "Assessing head impact sensor validity in the laboratory," *Summer Biomechanics, Bioengineering, and Biotransport Conference*, Snowbird, UT, 2015.

43. Rowson S, Daniel R, Cobb B, and Duma S, "Assessment of angular rate sensors to measure rotational head acceleration during impact testing," *Biomedical Engineering Society Annual Meeting*, San Antonio, TX, 2014.

44. Cobb B, MacAlister A, Young T, Kemper A, Rowson S, and Duma S, "Quantitative analysis of dummy headform shape for impact testing with football helmets," *Biomedical Engineering Society Annual Meeting*, San Antonio, TX, 2014.

45. Cobb B, Rowson S, and Duma S, "Quantitative analysis of biomechanical data with random measurement error," *Biomedical Engineering Society Annual Meeting*, San Antonio, TX, 2014.

46. Beeman S, Rowson S, and Duma S, "Quantification of toy sword kinematics with male and female pediatric volunteers," *Biomedical Engineering Society Annual Meeting,* San Antonio, TX, 2014.

47. Cobb BR, Rowson S, and Duma SM, "Quantifying uncertainty in distribution analyses of biomechanical data with random error," *World Congress of Biomechanics*, Boston, MA, 2014.

48. Cobb BR, MacAlister A, Young TJ, Kemper AR, Rowson S, and Duma SM, "Quantitative comparison of dummy headform shape and implications on laboratory testing of football helmets," *World Congress of Biomechanics*, Boston, MA, 2014.

49. Wilcox BJ, Beckwith JG, Greenwald RM, Raukar NP, Chu JJ, McAllister TW, Flashman LA, Maerlender AC, Duhaime AC, Rowson S, Duma SM, and Crisco JJ, "Sex differences in the rate and biomechanics of head impacts associated with diagnosed concussions," *World Congress of Biomechanics*, Boston, MA, 2014.

50. Daniel RW, Rowson S, and Duma SM, "Comparison of head impact exposure between skill and line position players in middle school football," *World Congress of Biomechanics*, Boston, MA, 2014.

51. Kemper AR, Santago AC, Stitzel JD, Sparks JL, and Duma SM, "Response of isolated whole human lungs in compression: effect of loading rate," *Biomedical Engineering Society Annual Meeting*, San Antonio, TX, 2014.

52. Alphonse VD, Kemper AR, and Duma SM, "Effect of orbital geometry on eye response to survivable primary blast overpressure," *Biomedical Engineering Society Annual Meeting*, San Antonio, TX, 2014.

53. Zwolski SM, LeRoith T, and Kemper AR, "Factors that contribute to inter-subject variation in human liver and spleen material properties," *Biomedical Engineering Society Annual Meeting*, San Antonio, TX, 2014.

54. Alphonse VD, Kemper AR, and Duma SM, "Porcine eye response to primary blast overpressure," *World Congress of Biomechanics*, Boston, MA, 2014.

55. Rowson S, Beyer JA, and Duma SM, "Characterization and experimental analysis of concussive impacts experienced by major league baseball catchers and umpires," *Biomedical Engineering Society Annual Meeting*, Seattle, WA, 2013.

56. Beeman SM, Kemper AR, Madigan ML, and Duma SM, "Kinetics of relaxed volunteers, braced volunteers, and Hybrid III ATD in low-speed frontal sled tests," *Biomedical Engineering Society Annual Meeting*, Seattle, WA, 2013.

57. Kemper AR, Santago AC, Stitzel JD, Sparks JL, and Duma SM, "Response of isolated whole human spleens in compression: effect of perfusion and loading rate," *Biomedical Engineering Society Annual Meeting*, Seattle, WA, 2013.

58. Young TJ, Daniel RW, Rowson S, and Duma SM, "Head impact exposure in youth football: elementary school ages 7 to 8 years and the effect of returning players," *Biomedical Engineering Society Annual Meeting*, Seattle, WA, 2013.

59. Cobb BR, Urban JE, Davenport EM, Rowson S, Duma SM, Maldjian JA, Witlow CT, and Powers AK, "Head impact exposure in youth football: elementary school ages 9 to 12 years and the effect of practice structure," *Biomedical Engineering Society Annual Meeting*, Seattle, WA, 2013.

60. Daniel RW, Rowson S, and Duma SM, "Head impact exposure in middle school football," *Biomedical Engineering Society Annual Meeting*, Seattle, WA, 2013.

61. Alphonse VD, Kemper AR, McNally C, Herring IP, Brown PJ, Stitzel JD, and Duma SM, "Porcine eye response to blast overpressure," *Biomedical Engineering Society Annual Meeting*, Seattle, WA, 2013.

62. Rowson S, Cobb BR, Daniel RW, MacAlister A, Young T, Kemper A, and Duma SM, "Rotational head acceleration measurement techniques and headform characteristics:

implications on helmet impact testing," *Proceedings of the 41st International Workshop on Human Subjects for Biomechanical Research*, Orlando, FL, 2013.

63. Kemper AR, Alphonse VD, McNally C, Herring IP, Brown PJ, Stitzel JD, and Duma SM, "Response of porcine eyes to blast overpressure: effects of overpressure severity and boundary conditions," *Proceedings of the 41st International Workshop on Human Subjects for Biomechanical Research*, Orlando, FL, 2013.

64. Urban JE, Daniel RW, Cobb BR, Young TJ, Davenport EM, Rowson S, Powers AK, Duma SM, and Stitzel JD, "Cumulative exposure risk of concussion for youth and high school football head impacts," *Ohio State Injury Biomechanics Symposium*, Columbus, OH, 2013.

65. Rowson S and Duma SM, "Predicting brain injury: the combined probability of concussion," *Biomedical Engineering Society Annual Meeting*, Atlanta, GA, 2012.

66. Rowson S, Daniel RW, and Duma SM, "Head impact exposure in youth football," *Biomedical Engineering Society Annual Meeting*, Atlanta, GA, 2012.

67. Rowson S, Daniel R, Young T, Cobb B, Stitzel J, Powers A, Maldjian J, Godwin D, Whitlow C, Urban J, Moody E, and Duma SM, "Head acceleration measurements during head impact in pediatric populations," *Proceedings of the 40th International Workshop on Human Subjects for Biomechanical Research*, Savannah, GA, 2012.

68. Rowson S and Duma SM, "Assessing the capability of helmets to prevent concussion: principles and applications of the STAR evaluation system," *American Society of Mechanical Engineers Summer Bioengineering Conference*, Fajardo, Puerto Rico, 2012.

69. Daniel R, Rowson S, and Duma SM, "Linear and angular head acceleration measurement collection in pediatric football," *American Society of Mechanical Engineers Summer Bioengineering Conference*, Fajardo, Puerto Rico, 2012.

70. Rowson S and Duma SM, "Brain injury prediction: assessing the combined probability of concussion," *Canadian Society of Biomechanics Conference*, Burnaby, British Columbia, Canada, 2012.

71. Porta DJ, Kemper AR, Beeman SM, and Duma SM, "Anatomical injury analysis of restrained cadavers in frontal collision testing" *Annual Meeting of the American Association of Clinical Anatomists*, Grenada, 2012.

72. Kemper AR, Beeman SM, Madigan ML, and Duma SM, "Effect of pre-impact bracing on human occupant muscle activation in low-speed frontal sled tests," *Biomedical Engineering Society Annual Meeting*, Atlanta, GA, 2012.

73. Kemper AR, Santago AC, Sparks JL, Stitzel JD, and Duma SM, "Biomechanical response of isolated whole human livers in compression: effect of perfusion," *Biomedical Engineering Annual Meeting*, Atlanta, GA, 2012.

74. Beeman SM, Kemper AR, and Duma SM, "Kinetics of relaxed and braced human volunteers in low-speed frontal sled tests," *Biomedical Engineering Society Annual Meeting*, Atlanta, GA, 2012.

75. Alphonse VD, Kemper AR, Strom BT, Beeman SM, and Duma SM, "Eye injuries from fireworks are caused by projectiles and not blast overpressure," *American Society of Mechanical Engineers Summer Bioengineering Conference*, Fajardo, Puerto Rico, 2012.

76. Kemper AR, Santago AC, Sparks JL, Stitzel JD, and Duma SM, "Biomechanical response of human liver and spleen parenchyma in uniaxial unconfined compression," *American Society of Mechanical Engineers Summer Bioengineering Conference*, Fajardo, Puerto Rico, 2012.

77. Alphonse VD, Kemper AR, Strom BT, Beeman SM, and Duma SM, "Human eye response to blast overpressure," *American Society of Mechanical Engineers Summer Bioengineering Conference*, Fajardo, Puerto Rico, 2012.

78. Beeman SM, Kemper AR, Madigan ML, and Duma SM, "Upper body kinematics of relaxed volunteers, braced volunteers, Hybrid III ATD, and PMHS in low-speed frontal sled tests," *American Society of Mechanical Engineers Summer Bioengineering Conference*, Fajardo, Puerto Rico, 2012.

79. Daniel RW, Rowson S, and Duma SM, "Linear and angular head acceleration measurement collection in pediatric football," *American Society of Mechanical Engineers Summer Bioengineering Conference*, Fajardo, Puerto Rico, 2012.

80. Beckwith J, Greenwald R, Chu J, Crisco J, Rowson S, Duma S, Broglio S, McAllister T, Guskiewicz K, Mihalik J, Anderson S, Schnebel B, Brolinson G, Lund B, and Collins M, "Severity and frequency of head impacts sustained by football player on days of diagnosed concussion," *9th World Congress on Brain Injury*, Edinburgh, Scotland, 2012.

81. Beckwith J, Greenwald R, Chu J, Crisco J, Rowson S, Duma S, Broglio S, McAllister T, Guskiewicz K, Mihalik J, Anderson S, Schnebel B, Brolinson G, Lund B, and Collins M, "Timing of concussion diagnosis is related to head impact exposure prior to injury," *9th World Congress on Brain Injury*, Edinburgh, Scotland, 2012.

82. Kemper AR, Beeman SM, and Duma SM, "Effect of Pre-Impact Bracing on Chest Compression of Human Occupants in Low-Speed Frontal Sled Tests," *Biomedical Engineering Society Annual Meeting*, Hartford, CT, 2011.

83. Kemper AR, Santago AC, Sparks JL, Stitzel JD, and Duma SM, "Biomechanical response of human liver and spleen parenchyma in uniaxial unconfined compression," *Biomedical Engineering Society Annual Meeting*, Hartford, CT, 2011.

84. Beeman SM, Kemper AR, and Duma SM, "Kinematics of relaxed volunteers, braced volunteers, and frontal ATD in low-speed frontal sled tests," *Biomedical Engineering Society Annual Meeting*, Hartford, CT, 2011.

85. Beeman SM, Kemper AR, Madigan ML, and Duma SM, "Effects of muscle activation on occupant kinematics in frontal sled tests," *American Society of Mechanical Engineers Summer Bioengineering Conference*, Farmington, PA, 2011.

86. Loftis KL, Halsey MG, Anthony EY, Duma SM, and Stitzel JD, "Pregnant female anthropometry from computed tomography scan for finite element model development," *Wake Forest University Graduate Student Research Day*, Winston-Salem, NC, 2011.

87. Stitzel JD, Weaver AA, Kennedy EA, and Duma SM, "Evaluation of different projectiles in matched experimental eye impact simulations," *Association for Research in Vision and Ophthalmology Annual Meeting*, Fort Lauderdale, FL, 2011.

88. Weaver AA, Kennedy EA, Duma SM, and Stitzel JD, “Evaluation of different projectiles in matched experimental eye impact simulations,” *Wake Forest University Graduate Student Research Day*, Winston-Salem, NC, 2011.

89. Weaver AA, Kennedy EA, Duma SM, and Stitzel JD, "Evaluation of different projectiles in matched experimental eye impact simulations," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2011.

90. Weaver AA, Loftis KL, Duma SM, and Stitzel JD. “Biomechanical modeling of different orbit anthropometries,” *Association for Research in Vision and Ophthalmology Annual Meeting*, Fort Lauderdale, FL, 2011.

91. Crisco JJ, Wilcox BJ, Beckwith JG, Chu JJ, Duhaime AC, Rowson S, Duma SM, Maerlender AC, and Greenwald RM, “Biomechanics of head impacts in American football players,” *American Society of Biomechanics Annual Meeting*, Long Beach, CA, 2011.

92. Rowson S and Duma SM, “Senior design capstone project: expanding on the basics,” *Biomedical Engineering Society Annual Meeting*, Hartford, CT, 2011.

93. Rowson S and Duma SM, “Rotational head acceleration and velocity associated with concussion in humans,” *Biomedical Engineering Society Annual Meeting*, Hartford, CT, 2011.

94. Rowson S and Duma S, “Development of the STAR evaluation system for football helmets,” *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2011.

95. Rowson S and Duma SM, “Rotational acceleration and velocity associated with concussions in humans,” *American Society of Mechanical Engineers Summer Bioengineering Conference*, Farmington, PA, 2011.

96. Daniel RW, Rowson S, Duma S, Mihalik J, and Guskiewicz K, “Investigation of effective mass differences for helmet to helmet impacts in football: role of the neck and implications on injury,” *Biomedical Engineering Society Annual Meeting*, Hartford, CT, 2011.

97. Weaver AA, Loftis KL, Duma SM, and Stitzel JD, “Biomechanical modeling of different orbit anthropometries,” *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Winston-Salem, NC, 2010.

98. Weaver AA, Kennedy EA, Duma SM, and Stitzel JD, “Evaluation of different projectiles in matched experimental eye impact simulations,” *American Society of Biomechanics Annual Meeting*, Providence, RI, 2010.

99. Weaver AA, Loftis KL, Duma SM, and Stitzel JD, “Biomechanical modeling of different orbit anthropometries,” *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

100. Weaver AA, Kennedy EA, Duma SM, and Stitzel JD, “Evaluation of different projectiles in matched experimental eye impact simulations,” *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

101. Loftis KL, Halsey MG, Yu MM, Anthony EY, Duma SM, and Stitzel JD, “Pregnant female anthropometry from computed tomography scans for finite element model development,” *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

102. Loftis KL, Weaver AA, Tan JC, Duma SM, and Stitzel JD, "CT based three-dimensional measurement of orbit and eye anthropometry," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

103. Rowson S and Duma SM, "High impact head accelerations from human volunteers," *Institute for Critical Technology and Applied Science Research Day*, Blacksburg, VA, 2010.

104. Rowson S and Duma S, "Relationships between linear and angular head acceleration from impact to human volunteers," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

105. Rowson S, McNally C, and Duma S, "Effect of shoe laces on in situ measurement of Achilles tendon mechanics," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

106. Rowson S, Shain K, Madigan M, and Duma S, "Head accelerations from baseballs impacting catcher's masks and implications on injury," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

107. Funk JR, Duma SM, Manoogian SJ, and Rowson S, "Development of a concussion risk curve using biomechanical data from collegiate football players," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

108. Cormier J, Manoogian S, Bisplinghoff J, Rowson S, Santago A, McNally C, Bolte J, and Duma S, "The tolerance of the nasal bone to blunt impact," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

109. Cormier J, Manoogian S, Bisplinghoff J, Rowson S, Santago A, McNally C, Bolte J, and Duma S, "The influence of the frontal sinus on fracture tolerance," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

110. Danelson K, Rowson S, Duma S, and Stitzel J, "Assessment of strain patterns in the brain from head acceleration from collegiate football players," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

111. Danelson KA, Rowson S, Goforth M, Dietter D, Brolinson G, Duma SM, and Stitzel JD, "Concussion and HITS. Head Impact Telemetry System," *U.S. Army Research Laboratory's Accelerative Injury Workshop,* Aberdeen, MD, 2010.

112. Kemper A, Beeman S, and Duma S, "Chest deflection of relaxed and braced human occupants in low severity frontal sled tests and non-censored rib fracture data in high severity PMHS frontal sled rests," *Proceedings of the 38th International Workshop on Human Subjects for Biomechanical Research*, Scottsdale, AZ, 2010.

113. Kemper A, McNally C, and Duma S, "Dynamic tensile material properties of human pelvic cortical bone," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

114. Kemper A, Stitzel J, McNally C, Kennedy E, and Duma S, "Rib fracture timing in dynamic belt tests with human cadavers," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

115. Kemper A, Santago A, Stitzel J, Sparks J, and Duma S, "Biomechanical response of human spleen parenchyma in tensile loading," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

116. Beeman S, Kemper A, Madigan M, and Duma S, "High-speed 3D motion analysis system for quantifying human subject kinematics during frontal sled tests," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

117. Beeman S, Kemper A, Madigan M, and Duma S, "Effects of muscle activation on occupant kinematics in frontal sled tests," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

118. Santago A, Kemper A, Sparks J, and Duma S, "Comparing the biomechanical response of porcine, bovine, and human liver tissue," *Biomedical Engineering Society Annual Meeting*, Austin, TX, 2010.

119. Beeman, S, Kemper, A, Madigan, M, and Duma, S, "Effects of muscle activation on occupant kinematics in frontal impacts," *Ohio State Injury Biomechanics Symposium*, Columbus, OH, 2010.

120. Danelson K, Rowson S, Duma S, and Stitzel J, "Assessment of strain patterns in the brain from real-world acceleration data from collegiate football players," *Ohio State Injury Biomechanics Symposium,* Columbus, OH, 2010.

121. Rowson S and Duma S, "In situ Achilles tendon measurement and the effect of footwear," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Winston-Salem, NC, 2010.

122. Gayzik FS, Hamilton CA, Tan JC, McNally C, Duma SM, Klinich KD, and Stitzel JD, "Image data collection protocol for full body finite element model development and review of VT-WFU CIB capabilities," *SAE Digital Human Modeling and SAFER Technical Meeting*, Gothenburg, Sweden, 2009.

123. Stitzel JD, Danelson KA, Rowson S, Duma SM, "Assessment of strain patterns in the brain from real-world acceleration data from collegiate football players," *International Brain Mapping & Intraoperative Surgical Planning Society*, 2009.

124. Moreno DP, Gayzik FS, Danelson KA, Showalter M, Duma SM, and Stitzel JD, "Anthropometric landmark and external contour development for human body finite element modeling." *Biomedical Engineering Society Annual Meeting*, Pittsburgh, PA, 2009.

125. Cormier J, Bisplinghoff J, Manoogian S, Rowson S, Santago A, McNally C, Bolte J, and Duma S, "The tolerance and response of the frontal bone to blunt impact," *Ohio State Injury Biomechanics Symposium*, Columbus, OH, 2009.

126. Rowson S and Duma S, "Every Newton hertz: investigating the mechanisms of brain injury," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2009.

127. Kemper, A, Stitzel, J, Sparks, J, and Duma, S "Macro to micro approach to characterizing human organs," *Proceedings of the 37th International Workshop on Human Subjects for Biomechanical Research*, Savannah, GA, 2009.

128. Rowson S, McNally C, and Duma S, "Effect of footwear on in situ measurement of Achilles tendon mechanics," *Biomedical Engineering Society Annual Meeting*, Pittsburgh, PA, 2009.

129. Rowson S and Duma S, "High impact head accelerations in human volunteers," *Biomedical Engineering Society Annual Meeting*, Pittsburgh, PA, 2009.

130. Kemper AR, McNally C, and Duma SM, "Quasi-linear viscoelastic characterization of human hip ligaments," *Biomedical Engineering Society Annual Meeting*, Pittsburgh, PA, 2009.

131. Kemper A, McNally C, and Duma S, "Influence of age on the tensile material properties of human rib cortical bone," *Biomedical Engineering Society Annual Meeting*, Pittsburg, PA, 2009.

132. Kemper A, McNally C, and Duma S, "Tensile and compressive material properties of human tibia cortical bone," *Biomedical Engineering Society Annual Meeting*, Pittsburg, PA, 2009.

133. Santago AC, Kemper AR, McNally C, Sparks JL, and Duma SM, "The effect of cell culture medium and hydration fluid on bovine liver tissue," *Biomedical Engineering Society Annual Meeting,* Pittsburgh, PA, 2009.

134. Santago AC, Kemper AR, McNally C, Sparks JL, and Duma SM, "Characterizing the biomechanical response of human liver in tension," *Biomedical Engineering Society Annual Meeting,* Pittsburgh, PA, 2009.

135. Bisplinghoff J, Kennedy E, and Duma S, "Dynamic material properties of human sclera," *Biomedical Engineering Society Annual Meeting*, Pittsburg, PA, 2009.

136. Beckwith J, Chu J, McAllister T, Maerlender A, Flashman L, Duhaime A, Crisco J, Duma S, Brolinson G, and Greenwald R, "Neurocognitive function and the severity of head impacts sustained in athletic competition," *American Society of Biomechanics Annual Meeting*, State College, PA, 2009.

137. Brainard L, Beckwith JG, Chu JJ, Crisco JJ, McAllister TW, Duhaime A, Maerlender AC, Duma SM, Brolinson G, and Greenwald R, "Gender differences in head impact acceleration in collegiate ice hockey," *American Society of Biomechanics Annual Meeting*, State College, PA, 2009.

138. Beckwith JG, Chu JJ, Crisco JJ, McAllister TW, Duma SM, Brolinson G, and Greenwald R, "Severity of head impacts resulting in mild traumatic brain injury," *American Society of Biomechanics Annual Meeting*, State College, PA, 2009.

139. Loftis KL, Halsey MG, Yu MM, Anthony EY, Duma SM, and Stitzel JD, "Pregnant female anthropometry from computed tomography scans for finite element model development," *Proceedings of the 36th International Workshop on Human Subjects for Biomechanical Research*, San Antonio, TX, 2008.

140. Loftis KL, Halsey MG, Anthony EY, Duma SM, and Stitzel JD, "Pregnant female anthropometry from CT scans for finite element model development," *Ohio State Injury Biomechanics Symposium*, Columbus, OH, 2008.

141. Santago AC, Cormier JM, Duma SM, Yoganandan N, and Pintar FA, "Humerus and forearm fracture bending risk function for the 50th percentile male" *Ohio State Injury Biomechanics Symposium*, Columbus, OH, 2008.

142. Gayzik FS, Hamilton CA, Tan JC, McNally C, Duma SM, Klinich KD, and Stitzel JD, "A multi-modality image data collection protocol for full body finite element model development," *Proceedings of the 36th International Workshop on Human Subjects for Biomechanical Research*, San Antonio, TX, 2008.

143. Rowson S and Duma S, "Evaluation of the load limiting capabilities of football neck collars using anthropomorphic test devices," *Ohio State Injury Biomechanics Symposium*, Columbus, OH, 2008.

144. Duma S, Rowson S, Hardy W, Brolinson G, and Goforth M, "The biomechanical basis of mild traumatic brain injury," *American Osteopathic Association Scientific Meeting*, Las Vegas, NV, 2008.

145. Brolinson G, Duma S, and Rowson S, "Clinical and biomechanical implications of Achilles tendon injury," *American Osteopathic Association Scientific Meeting*, Las Vegas, NV, 2008.

146. Duma S, Rowson S, and Brolinson G, "Neck protective devices," *American Osteopathic Association Scientific Meeting*, Las Vegas, NV, 2008.

147. Bisplinghoff JA, McNally C, Herring IP, Brozoski FT, Stitzel J, and Duma SM, "High rate internal pressurization of the human eye to determine dynamic material properties," *Proceedings of the 36th International Workshop on Human Subjects for Biomechanical Research*, San Antonio, TX, 2008.

148. Santago A, Cormier J, Duma S, Yoganandan N, and Pintar F, "Humerus and forearm bending risk functions for the 50th percentile male," *Ohio State Injury Biomechanics Symposium*, Columbus, OH, 2008.

149. Bisplinghoff JA, McNally C, Herring IP, Brozoski FT, and Duma SM, "High rate internal pressurization of the human eye to determine dynamic material properties," *Ohio State Injury Biomechanics Symposium*, Columbus, OH, 2008.

150. Rowson S and Duma S, "Evaluation of head and neck injury risk in football," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Winston-Salem, NC, 2008.

151. Rowson S and Duma SM, "Biomechanical response of the human head to dynamic impact," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Winston-Salem, NC, 2008.

152. Kennedy EA, Duma SM, Depinet P, and Brozoski F, "Development of an advanced headform for the prediction of eye injuries," *American Society of Biomechanics Annual Meeting*, Stanford, CA, 2007.

153. Kennedy EA and Duma SM, "Review of eye injuries and risk evaluation for consumer products," *International Consumer Products Health & Safety Organization*, Orlando, FL, 2007.

154. Kemper A, McNally C, Manoogian S, and Duma S, "Determining non-censored rib fracture data during side impact loading," *Proceedings of the 35th International Workshop on Human Subjects for Biomechanical Research*, San Diego, CA, 2007.

155. Manoogian SJ, McNally C, Duma SM, "Protecting the pregnant occupant: dynamic material properties of placenta," *Proceedings of the 35th International Workshop on Human Subjects for Biomechanical Research*, San Diego, CA, 2007.

156. Rowson S, Chu JJ, Beckwith JG, Greenwald RM, Stitzel JD, Kimpara H, and Duma SM, "Six degree of freedom head acceleration measurements in football players," *Proceedings of the 35th*

International Workshop on Human Subjects for Biomechanical Research, San Diego, CA, 2007.

116. Kemper AR, McNally C, Wyatt CL, and Duma SM, "Controlling boundary conditions and specimen preparation for testing human ribs: effects of periosteum, hydration, and strain gages," *Proceedings of the 34th International Workshop on Human Subjects for Biomechanical Research*, Dearborn, MI, 2006.

117. Funk JR, Duma SM, Manoogian SJ, and Rowson S, "Development of concussion risk curves based on head impact data from collegiate football players," *Proceedings of the 34th International Workshop on Human Subjects for Biomechanical Research*, Dearborn, MI, 2006.

Daly M, Duma SM, and Stitzel JD, "Retrospective identification of subject anthropometry using computed tomography of the leg," *American Society of Biomechanics Annual Meeting*, Blacksburg, VA, 2006.

157. Gayzik S, Bostrom O, Duma S, and Stitzel J, "An experimental and finite element study of the porcine carotid artery under dynamic loading," *American Society of Biomechanics Annual Meeting*, Blacksburg, VA, 2006.

158. Funk J and Duma S, "Biomechanical risk estimates for concussion in collegiate football players," *American Society of Biomechanics Annual Meeting*, Blacksburg, VA, 2006.

159. Funk JR, Duma SM, Manoogian SJ, and Rowson S, "Development of concussion risk curves based on head impact data from collegiate football players." *Proceedings of the 34th International Workshop on Human Subjects for Biomechanical Research*, Dearborn, MI, 2006.

160. Manoogian S, Kennedy E, Wilson K, Alem N, and Duma S, "Predicting neck injuries due to head supported mass," *American Society of Biomechanics Annual Meeting*, Blacksburg, VA, 2006.

161. Kennedy E, Herring I, McNally C, and Duma S, "The effects of extra ocular muscles on the dynamic response of the human eye under impact and their influence on globe rupture," *American Society of Biomechanics Annual Meeting*, Blacksburg, VA, 2006

162. Kemper A, McNally C, McNeely D, Matsuoka F, and Duma S, "Compressive stiffness properties of human lumbar intervertebral discs and the influence of strain rate," *American Society of Biomechanics Annual Meeting*, Blacksburg, VA, 2006.

163. Kemper AR, McNally C, Wyatt C, and Duma SM, "Controlling boundary conditions and specimen preparation for testing human ribs: effects of periosteum, hydration, and strain gages," *Proceedings of the 34th International Workshop on Human Subjects for Biomechanical Research,* Dearborn, MI, 2006.

164. McNeely D, McNally C, Brolinson G, and Duma S, "Force limiting capabilities of neck devices in collegiate football impacts," *American Society of Biomechanics Annual Meeting*, Blacksburg, VA, 2006.

165. Duma S, Caine J, Coleman D, Langmead M, Leung K, Ng T, Weatherholtz J, Whitehair M, and Wilson K, "Development of an active hip protection system: design for hip fracture prevention and increased compliance," *American Society of Biomechanics Annual Meeting*, Blacksburg, VA, 2006.

166. Duma S, Moorcroft D, Duma G, and Stitzel J, "Pregnant occupant biomechanics in far-side impacts: the effects of seat friction and console height," *World Congress of Biomechanics,* Munich, Germany, 2006.

167. Kennedy E and Duma S, "Airsoft guns and eye injuries," *Association for Research in Vision and Ophthalmology Annual Meeting*, Fort Lauderdale, FL, 2006.

168. Duma S and Kennedy E, "Effects of eye muscles on eye injuries," *Association for Research in Vision and Ophthalmology Annual Meeting*, Fort Lauderdale, FL, 2006.

169. Stitzel J, Ng T, and Duma S, "Eye injury analysis techniques," *Association for Research in Vision and Ophthalmology Annual Meeting*, Fort Lauderdale, FL, 2006.

170. Gayzik FS, Duma SM, and Stitzel JD, "Biomechanical analysis of arterial loading: carotid injury biomechanics." *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2006.

171. Gayzik S, Tan J, Duma SM, and Stitzel JD, "Mesh development for a finite element model of the carotid artery," *Wake Forest University Graduate Student Research Day*, Winston-Salem, NC, 2006.

118. Stitzel J, Gayzik S, Loftis K, and Duma S, "Age-related modeling of human rib-cage geometry," *Proceedings of the 33nd International Workshop on Human Subjects for Biomechanical Research*, Washington, DC, 2005.

119. Kennedy EA, Bonivitch AR, Herring IP, McNally C, Manoogian SJ, Stitzel JD, and Duma SM, "Effects of the extraocular muscles on the response of the human eye under static and dynamic loading conditions," *Proceedings of the 33nd International Workshop on Human Subjects for Biomechanical Research*, Washington, DC, 2005.

172. Rath A, Manoogian S, Duma S, Bolton B, and Crandall J, "A fiber optic based sensor for measuring chest and abdominal deflection under impact loading," *American Society of Biomechanics Annual Meeting*, Cleveland, OH, 2005.

173. Duma S, Moorcroft D, Stitzel J, and Duma G, "A computational model of the pregnant occupant: local uterine compression affects the risk of fetal injury," *American Society of Biomechanics Annual Meeting*, Cleveland, OH, 2005.

174. Manoogian S, McNeely D, Goforth M, Brolinson G, and Duma S, "Head acceleration is less than 10 percent of helmet acceleration during football impact," *American Society of Biomechanics Annual Meeting*, Cleveland, OH, 2005.

175. McNeely D, Manoogian S, Duma S, Chu J, Beckwith J, Greenwald R, Brolinson G, and Goforth M, "Cumulative head acceleration in college football players differs by position," *American Society of Biomechanics Annual Meeting*, Cleveland, OH, 2005.

176. Kennedy E, Voorhies K, Rath A, Brozoski F, and Duma S, "Rupture pressures for human and porcine eyes under static and dynamic loading," *American Society of Biomechanics Annual Meeting*, Cleveland, OH, 2005.

177. Duma S, Kennedy E, Herring I, and Rath A, "Static and dynamic rupture pressures of the human and porcine eyes," *Association for Research in Vision and Ophthalmology Annual Meeting*, Fort Lauderdale, FL, 2005.

178. Stitzel J, Duma S, and Gabler C, "Technology roadmap update," *National Capitol Region Biomedical Engineering Research Conference*, Washington, D.C., 2005.

179. Sitzel J, Kemper A, and Duma S, "Myopia and hyperopia's effect on probability of globe rupture due to a foreign body impact," *Association for Research in Vision and Ophthalmology Annual Meeting*, Fort Lauderdale, FL, 2005.

180. Kennedy E, Duma S, Ng T, Stitzel J, and Kuhn F, "Risk functions for the prediction of specific eye injuries using projectile data," *Association for Research in Vision and Ophthalmology Annual Meeting*, Fort Lauderdale, FL, 2005.

181. Manoogian S, McNeely D, Duma S, and Brolinson G, "Analysis of linear head accelerations from collegiate football impacts," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Meadows of Dan, VA, 2005.

182. Kemper A, McNally C, Kennedy E, Manoogian S, Rath A, Stitzel J, and Duma S, "Material properties of human rib cortical bone from dynamic tension coupon testing," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Meadows of Dan, VA, 2005.

183. Rath A, Manoogian S, Kennedy E, Herring I, Stitzel J, and Duma S, "The effects of extraocular muscles on eye biomechanics," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Meadows of Dan, VA, 2005.

184. Gayzik S, Hoth J, Mercier J, Gage D, Morton K, Duma S, Payne M, and Stitzel J, "Development of a finite element-based injury metric for pulmonary contusion part I: results of preliminary studies with rat lung," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Meadows of Dan, VA, 2005.

185. Kennedy E, Duma S, Ng T, Stitzel J, and Kuhn F, "Risk functions for the prediction of specific eye injuries using projectile data," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Meadows of Dan, VA, 2005.

186. Duma S, Stitzel J, Kemper A, McNally C, Kennedy E, and Matsuoka F, "A method to acquire non-censored rib fracture data during dynamic belt loading tests," *Proceedings of the 32nd International Workshop on Human Subjects for Biomechanical Research*, Nashville, TN, 2004.

187. Kemper A, McNally C, Kennedy E, Rath A, Manoogian S, Stitzel J, Duma S, Matsuoka F, and Hasegawa J, "Methods for dynamic material testing of human cortical bone specimens," *Proceedings of the 32nd International Workshop on Human Subjects for Biomechanical Research*, Nashville, TN, 2004.

188. Duma S, Manoogian S, Brolinson G, Goforth M, Donnenwerth J, Greenwald R, Chu J, Bussone B, Stitzel J, and Crisco T, "Measuring real time head accelerations in collegiate football players," *American Society of Biomechanics Annual Meeting*, Portland, OR, 2004.

189. Stitzel J, Duma S, and Cormier J, "Large deformation and fluid modeling in the anterior chamber in impacts to the human eye," *American Society of Biomechanics Annual Meeting*, Portland, OR, 2004.

190. Duma S, Stitzel J, and Yeatts P, "Incidence of ocular injury in U.S. automobile crashes," *Association for Research in Vision and Ophthalmology Annual Meeting*, Fort Lauderdale, FL, 2004.

191. Stitzel J, Duma S, and Yeatts P, "A finite element model of the human eye for trauma prediction," *Association for Research in Vision and Ophthalmology Annual Meeting*, Fort Lauderdale, FL, 2004.

192. Hansen G, Kennedy E, Rath A, McNally C, Kemper A, Smith E, Brolinson G, and Duma S, "Upper extremity interaction with a Black Hawk helicopter side airbag: injury criteria for dynamic hyperextension of the female elbow joint," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Winston-Salem, NC, 2004.

193. Kennedy E, Hurst W, Stitzel J, Cormier J, Hansen G, Smith E, and Duma S, "Dynamic bending fracture criteria of the human femur for lateral and posterior loading applications," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Winston-Salem, NC, 2004.

194. Duma S, Manoogian S, Brolinson G, Goforth M, Donnenwerth J, Greenwald R, Chu J, Bussone B, Stitzel J, and Crisco T, "Measuring *in situ* head accelerations and evaluating clinical outcomes in collegiate football players," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Winston-Salem, NC, 2004.

195. Manoogian S, Bussone W, Stitzel J, Duma S, Brolinson G, Donnenworth R, Chu J, and Crisco T, "Measuring *in situ* head accelerations and evaluating clinical outcomes in collegiate football players," *Proceedings of the 31st International Workshop on Human Subjects for Biomechanical Research*, San Diego, CA, 2003.

196. Cormier J, Stitzel J, Duma S, Matsuoka F, "Microstructural analysis of osteon orientation in human rib cortical bone," *Proceedings of the 31st International Workshop on Human Subjects for Biomechanical Research*, San Diego, CA, 2003.

197. Cormier J and Duma S, "Occupant interaction with a deploying pelvic restraint cushion," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2003.

198. Hansen G, and Duma S, "Incidence of elderly eye injuries in automobile crashes: the effects of lens stiffness as a function of age," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2003.

199. Hurst W and Duma S, "Spring mediated cranioplasty for the treatment of craniosynostosis," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2003.

200. Voorhies K and Duma S, "Static and dynamic rupture stress of human and porcine eyes," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2003.

201. Tordonato D, Duma S, "The effects of freezing on the mechanical properties of articular cartilage," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2003.

202. Kennedy E and Duma S, "Effects of head-spine complex orientation on results in vertical acceleration fields," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2003.

203. Stitzel J and Duma S, "A nonlinear finite element model of the eye with experimental validation for the prediction of globe rupture," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2003.

204. Cormier J and Duma SM, "Predicting and evaluating facial fractures from baseball impact," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2003.

205. Stitzel J and Duma S, "Material property development for the elderly thorax," *VT-WFU School of Biomedical Engineering and Sciences Annual Graduate Student Research Symposium*, Blacksburg, VA, 2003.

206. Cormier J, Stitzel J, Hurst W, Duma S, Porta D, and Jones J, "Predicting and evaluating orbital fractures from baseball impact," *Proceedings of the 30th International Workshop on Human Subjects for Biomechanical Research*, Ponte Verda, FL, 2002.

207. Cormier J, Stitzel J, Duma S, and Hurst W, "Predicting and evaluating zygoma fractures from baseball impact," *Proceedings of the 30th International Workshop on Human Subjects for Biomechanical Research*, Ponte Verda, FL, 2002.

208. Hurst W, Cormier J, Stitzel J, Duma S, Holden M, and Lees C, "Evaluation of airbag induced skin abrasions using high-rate shear loading," *Proceedings of the 30th International Workshop on Human Subjects for Biomechanical Research*, Ponte Verda, FL, 2002.

209. Stitzel J, Power E, Cormier J, Hurst W, Herring I, and Duma S, "Computational modeling and experimental validation of human eye interaction with high speed foam particles," *World Congress of Biomechanics*, Calgary, Canada, 2002.

210. Duma S, Boggess B, Crandall J, and MacMahon C, "Injury risk function for the small female wrist," *World Congress of Biomechanics*, Calgary, Canada, 2002.

211. Cormier J, Hurst W, Stitzel J, Herring I, and Duma S, "Investigation of skin abrasion injuries from high rate shear loading," *World Congress of Biomechanics*, Calgary, Canada, 2002.

212. Hurst W, Cormier J, Herring I, and Duma S, "Sonomicrometric measurements of eye displacements," *World Congress of Biomechanics*, Calgary, Canada, 2002.

213. Cormier J, Stitzel J, Hurst W, and Duma S, "High speed and continuous pressure measurements: comparison of active pressure sensors and pressure film," *World Congress of Biomechanics*, Calgary, Canada, 2002.

214. Crowley J, Bass C, Duma S, Herring I, Brozoski F, Davis M, and Stitzel J, "Potential interaction of inflatable restraints and night vision goggles in helicopter mishaps," *Aerospace Medical Association Annual Meeting*, Montreal, Canada, May, 2002.

215. Jernigan M and Duma S, "Statistical analysis and computational modeling of injuries in automobile crashes," *CBME and WFU Biomedical Engineering Student Research Symposium*, Blacksburg, VA, 2002.

216. Jernigan M and Duma S, "Analysis of burn injuries in frontal automobile crashes," *CBME and WFU Biomedical Engineering Student Research Symposium*, Blacksburg, VA, 2002.

217. Hurst W, Cormier J, Herring I, and Duma S, "Sonomicrometric measurements for eye displacements," *CBME and WFU Biomedical Engineering Student Research Symposium*, Blacksburg, VA, 2002.

218. Cormier J, Hurst W, Stitzel J, Duma S, "Investigation of skin abrasion injuries from high rate shear loading," *CBME and WFU Biomedical Engineering Student Research Symposium*, Blacksburg, VA, 2002.

219. Moorcroft D, Jernigan M, Stitzel J, Duma G, and Duma S, "A finite element model of the pregnant female occupant: analysis of injury mechanisms and restraint systems," *CBME and WFU Biomedical Engineering Student Research Symposium*, Blacksburg, VA, 2002.

220. Stitzel J, Power E, Cormier J, Hurst W, Herring I, and Duma S, "Computational modeling and experimental validation of globe deformation due to impact with high speed foam particles," *CBME and WFU Biomedical Engineering Student Research Symposium*, Blacksburg, VA, 2002.

221. Stitzel J, Vinger P, and Duma S, "On the risk of zygoma fracture from baseball loading," *CBME and WFU Biomedical Engineering Student Research Symposium*, Blacksburg, VA, May, 2002.

222. Duma S, Boggess B, Crandall J, Mac Mahon C, "Axial loading injury tolerance for the small female wrist," *Proceedings of the 29th International Workshop on Human Subjects for Biomechanical Research*, San Antonio, TX, 2001.

223. Power E, Duma S, Stitzel J, Herring I, West R, Bass C, Crowley J, and Brozoski F, "A nonlinear finite element model of the human eye to investigate ocular injuries from night vision goggles," *Proceedings of the 29th International Workshop on Human Subjects for Biomechanical Research*, San Antonio, TX, 2001.

224. Duma SM, Boggess BM, and Crandall JR, "Wrist and elbow loading during side air bag deployment," *American Society of Biomechanics Annual Meeting*, San Diego, CA, 2001.

225. Stitzel JD, Vinger PF, and Duma SM, "On the risk of zygoma fracture from baseball roading," *American Society of Biomechanics Annual Meeting*, San Diego, CA, 2001.

226. Power ED, Stitzel JD, West RL, Herring IP, and Duma SM, "A nonlinear finite element model of the human eye for large deformation loading," *American Society of Biomechanics Annual Meeting*, San Diego, CA, 2001.

227. Duma SM, Power E, Stitzel J, Jernigan M, Herring I, Picket P, and Bass C, "The porcine eye as a surrogate model for the human eye: anatomical, mechanical, and injury relationships," *Proceedings of the 28th International Workshop on Human Subjects for Biomechanical Research*, Atlanta, GA, 2000.

228. Duma SM, Boggess BM, Sieveka EM, and Crandall JR, "The effect of shoulder translation and forearm pronation on upper extremity loading during side air bag deployment," *American Society of Biomechanics Annual Meeting*, Chicago, IL, 2000.

229. Duma SM, Boggess BM, and Crandall JR, "Evaluation of upper extremity injuries from lateral air bag deployment," *Proceedings of the Technical Cooperative Program Workshop: Inflatable Restraints in Aviation*, Huntsville, AL, 1999.

230. Duma SM, Schreiber PH, McMaster JD, Bass CR, and Pilkey WD, "Fracture tolerance of the male forearm: the effect of pronation versus supination," *American Society of Biomechanics Annual Meeting*, Pittsburgh, PA, 1999.

231. Crandall JR, Bass CR, Duma SM, and Pilkey WD, "Cadaver and Hybrid III out-of-position testing using driver airbags," *World Congress of Biomechanics*, Sapporo, Japan, 1998.

232. Duma SM, Ryan LP, and Crandall JR, "Determination of bone mineral content in cadaveric test specimens," *Proceedings of the 26th International Workshop on Human Subjects for Biomechanical Research*, Tempe, AZ, 1998.

233. Pellettiere JA, Duma SM, Bass CR, and Pilkey WD, "Strength of the female upper extremity," *Proceedings from the NATO/RTO Specialist's Meeting: Models for Aircrew Safety Assessment*, Dayton, OH, 1998.

234. Duma SM, Porta DJ, and Kress TA, "Methodology for using in situ cadaver eyes for the evaluation of blunt ocular trauma," *Experimental Biology: Annual Meeting of the Professional Research Scientists*, New Orleans, LA, 1997.

235. Duma SM, Crandall JR, Turner SK, Simmons RJ, and Pilkey WD, "A protocol system for testing biohazardous materials in a research facility," *International System Safety Conference*, Washington, DC, 1997.

236. Duma SM, Crandall JR, Rudd RW, and Pilkey WD, "A review of the proposed changes in the federal automotive airbag design standard," *International System Safety Conference*, Washington, DC, 1997.

237. Rudd RW, Crandall JR, Duma SM, and Pilkey WD, "A discussion of lower extremity injuries in automobile crashes," *International System Safety Conference*, Washington, DC, 1997.

238. Duma SM, Kress TA, Porta DJ, Martin PG, Simmons RJ, Alexander CL, and Woods CD, "Airbag-induced eye injuries: dummy and cadaveric experiments," *International System Safety Conference*, Washington, DC, 1997.

239. Duma SM, Bass CR, Crandall JR, and Pilkey WD, "Examination of airbag-induced upper extremity injuries," *International System Safety Conference*, Washington, DC, 1997.

240. Kress TA, Porta DJ, Alexander CL, Snider JN, Fuller PM, Duma SM, Mullinex L, and Halstead D, "Experimental evaluation of air bag induced eye injury using a humanoid dummy head and porcine eyes," *Experimental Biology: Annual Meeting of the Professional Research Scientists*, Washington, DC, 1996.

241. Duma SM, Kress TA, Porta DJ, and Woods CD, "An experimental study of airbag-induced eye injuries," *Proceedings of the 24th International Workshop on Human Subjects for Biomechanical Research*, Albuquerque, NM, 1996.

242. Bass CR, Duma SM, Crandall JR, Micek TJ, Sieveka EM, Lange MJ, Grillo NR, Martin PG, and Pilkey WD, "Airbag interaction with cadaveric upper extremities," *Proceedings of the 24th International Workshop on Human Subjects for Biomechanical Research*, Albuquerque, NM, 1996.

243. Duma SM, Simmons RJ, Booher RI, Haarman KA, Porta DJ, Kress TA, and Guyer SX, "Outbreak: an examination of a university's biohazard laboratory and discussion of its safety implications," *International System Safety Conference*, Albuquerque, NM, 1996.

244. Porta DJ, Kress TA, Fuller PM, Snider JN, Obergfell AK, Duma SM, and Frick SJ, "Determination of human cadaver eye injuries after trauma experimentation," *Proceedings of the 23rd International Workshop on Human Subjects for Biomechanical Research*, San Diego, CA, 1995.

Books

1. Duma S, Concussion Perspectives: Medicine, Science, Engineering and Society, Kendall Hunt Publishing, Dubuque IA, 2023. ISBN 9798765788288

2. Duma S, Rowson S, Concussion Perspectives: Medicine, Science, Engineering and Society, 2nd Edition, Kendall Hunt Publishing, Dubuque IA, 2024. ISBN 9798385141395

3. Duma S, Rowson S, Helmet Design: From Biomechanics to Health & Social Disparities in Sports, Kendall Hunt Publishing, Dubuque IA, 2024. ISBN 97983855114955

4. Dingus T, Rowson S, Duma S, Automobile Safety, Kendall Hunt Publishing, Dubuque IA, 2025. ISBN is 9798385154319

5. Duma S, *Pregnant occupant biomechanics: advances in automobile safety research*, Society of Automotive Engineers, Warrendale PA, 344 pages, 2011.

6. Duma T and Duma S, *The Team Player*, Lulu Publishing Company, 245 pages, 2008.

Book Chapters

1. Rowson B, Tyson A, Rowson S, and Duma SM, "Measuring head impacts: accelerometers and other sensors," *Sports Neurology, Volume 158 of the Handbook of Clinical Neurology,* 2018.

2. Rowson B, Rowson S, and Duma SM, "Biomechanical forces resulting in brain injury," *Textbook of Traumatic Brain Injury*, 3rd Edition, 2017.

3. Duma SM and Rowson S, "The biomechanics of concussion: 60 years of experimental research," *Concussions in Athletics*, pp. 115-137, 2014.

APPENDIX B

APPENDIX B – LIST OF MATERIALS CONSIDERED

Exhibit No.	Document
1001	U.S. Patent No. 9,414,635 (USP635)
1003	Prosecution History for U.S. Patent No. 9,414,635 (Knight-635-FH)
1004	U.S. Patent Pub. 2012/0198604 (Weber)
1005	Int'l Patent App. Pub. No. WO 2001/045526 (VonHolst)
1006	Int'l Patent App. Pub. No. WO 2011/139224 (Halldin)
1007	U.S. Patent Application Publication No. 2013/0122256 (Kleiven)
1009	U.S. Patent Application Publication No. 2004/0250340 (Piper)
1010	U.S. Patent Application Publication No. 2006/0059606 (Ferrara-2006)
1011	U.S. Patent No. 6,996,856 (Puchalski)
1012	U.S. Patent No. 10,238,162 (Knight-162)
1013	Prosecution History for U.S. Patent No. 10,238,162 (Knight-162-FH)
1014	U.S. Provisional Application No, 61/462914 (WeberProv)
1015	U.S. Provisional Application No. 61/333817 (HalldinProv)
1016	U.S. Patent Application Publication No. 2008/0066217 (Depreitere)
1017	U.S. Patent No. 3,872,511 (Nichols)

Exhibit No.	Document
1018	U.S. Patent Application No 2007/0190293 (Ferrara-2007)
1019	U.S. Patent Application No. 2007/0068755 (Hawkins)
1020	Int'l Patent App. Pub. WO 2008/046196 (Cripton)
1021	Pons-Poblet, *The Vierendeel Truss: Past And Present Of An Innovative Typology*, 15 Arquitetura Revista 193 (2019) (Pons-Poblet)
1022	Kis et al., *Rotational Acceleration Measurements –Evaluating Helmet Protection*, 31 Can. J. Neurol. Sci. 499 (2004) (Kis-2004)
1023	Int'l Patent App. Pub. No. WO 1996/014768 (Phillips)
1024	U.S. Patent Application Publication No. 2001/0032351 (Nakayama)
1025	Newman, *Modern Sports Helmet – Their History, Science, and Art* (2007) (Newman)
1026	Kleiven, *A Parametric Study of Energy Absorbing Foams For Head Injury Prevention*, Technical Paper Number 07-0385, 20th Int'l Tech. Conf. on Enhanced Safety of Vehicles (June 18-21, 2007) (Kleiven-2007)
1028	Aare, *A New Laboratory Rig for Evaluating Helmets Subject to Oblique Impacts*, 4 Traffic Injury Prevention 240 (2003) (Aare-2003)
1029	U.S. Provisional App. No. 61/510,401 (401Prov)

Exhibit No.	Document
1030	U.S. Patent No. 8,863,319 (USP319)
1031	Bosch, *Crash helmet testing and design specifications* (Jan. 1, 2006) (Ph.D. Thesis, Eindhoven University of Technology) (Bosch)
1032	Mills & Gilchrist, *Bicycle Helmet Design*, 220 Proceedings of the Institution of Mechanical Engineers Part L Journal of Materials Design and Applications 167 (2006) (Mills-2006)
1033	Smith, *Diffuse Axonal Injury in Head Trauma*, 18 J. Head Trauma Rehab. 307 (2003) (Smith-2003)
1034	Jans, *Bike Helmet Anatomy*, https://www.jans.com/anatomy-of-a-bike-helmet?srsltid=AfmBOooriodHXEC54CbWtD0foK5WSXu8-gN0vaAh1lq96kCKdGHJ68FJ (Jans)
1036	International Polymer Solutions Inc., *Polycarbonate*, https://www.ipolymer.com/pdf/Polycarbonate.pdf (Intl-Polymer-Solutions)
1037	Universal Foam Products, Physical Properties of Expanded Polystyrene, https://univfoam.com/wp-content/uploads/2015/07/EPS-Data-Sheet.pdf (Universal-Foam-Products)
1038	Duma, *Analysis of Real-time Head Accelerations in Collegiate Football Players*, 15 Clin. J. Sports Med. 3 (2005) (Duma-2005)

Exhibit No.	Document
1039	Ommaya, *Chapter 13: Biomechanics of Head Injury: Experimental Aspects, in* The Biomechanics of Trauma 245 (1985) (Ommaya-1985)
1040	Viano, *Injury Biomechanics Research: An Essential Element in the Prevention of Trauma*, 22 J. Biomechanics 403 (1989) (Viano-1989)
1041	English Translation of Japanese Unexamined Patent Application Publication No. JP2006-016740 (Dotsuko)
1042	Japanese Unexamined Patent Application Publication No. JP2006-016740 (Dotsuko-Original-Japanese)
1043	U.S. Patent No. 5,353,437 (Field)
1047	U.S. Patent Application Publication No. 2004/0117896 (Madey)
1049	EPSOLE, *What Is EPS Material: The Complete Guide to EPS Material* (April 15, 2024), https://epsole.com/what-is-eps-material/ (Epsole)
1050	U.S. Patent 9,516,909 (USP909)

APPENDIX C

APPENDIX C – CHALLENGED CLAIMS

Claim No.	Challenged Claim Language	Grounds for Finding Claim Invalid
1[pre]	A helmet comprising:	Ground 1 Ground 2 Ground 3 Ground 4 Ground 6
1[a]	an outer shell layer;	
1[b]	an inner shell layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner shell layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,	
1[c]	the inner shell layer configured to conform to a human head;	
1[d]	a chin strap attached to the inner shell layer to maintain the position of the inner shell layer on the human head during rotational force impact while the outer shell layer is allowed to slide.	
2	The helmet of claim 1, wherein the shear mechanism is a shear layer.	Ground 1 Ground 2 Ground 3 Ground 4 Ground 6
3	The helmet of claim 2, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner shell layer.	Ground 1 Ground 2 Ground 3 Ground 4 Ground 6

Claim No.	Challenged Claim Language	Grounds for Finding Claim Invalid
4	The helmet of claim 3, wherein the inner shell layer is connected to the shear layer, the inner shell layer configured to conform to a human head, the inner shell layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer.	Ground 1 Ground 2 Ground 3
6	The helmet of claim 1, wherein the first absorptive/dissipative material comprises a fluid.	Ground 1 Ground 2 Ground 3
8	The helmet of claim 1, wherein a lining layer is connected to the inner shell layer, wherein the lining layer is configured to conform to a human head.	Ground 1 Ground 2 Ground 3 Ground 5 Ground 6
9[pre]	Protective gear comprising:	Ground 1 Ground 2 Ground 3 Ground 4 Ground 6
9[a]	an outer shell layer;	
9[b]	an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,	
9[c]	the inner conforming layer configured to conform to a human head;	
9[d]	A chin strap attached to the inner conforming layer to maintain the position of the inner	

Claim No.	Challenged Claim Language	Grounds for Finding Claim Invalid
	conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide	
10	The protective gear of claim 9, wherein the shear mechanism is a shear layer.	Ground 1 Ground 2 Ground 3 Ground 4 Ground 6
11	The protective gear of claim 10, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer.	Ground 1 Ground 2 Ground 3 Ground 4 Ground 6
12	The protective gear of claim 11, wherein the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer.	Ground 1 Ground 2 Ground 3

Claim No.	Challenged Claim Language	Grounds for Finding Claim Invalid
14	The protective gear of claim 9, wherein the first absorptive/dissipative material comprises a fluid.	Ground 1 Ground 2 Ground 3
16	The protective gear of claim 9, wherein the inner conforming layer is associated with a lining material configured to conform to a human head.	Ground 1 Ground 2 Ground 3 Ground 5 Ground 6
17[pre]	A helmet comprising:	Ground 1 Ground 2 Ground 3 Ground 4 Ground 6
17[a]	an outer shell layer;	
17[b]	an inner conforming layer connected to the outer shell layer through a shear mechanism allowing the outer shell layer to slide relative to the inner conforming layer, wherein the shear mechanism includes a first energy transformer having a first absorptive/dissipative material,	
17[c]	the inner conforming layer configured to conform to a human head;	
17[d]	A chin strap attached to the inner conforming layer to maintain the position of the inner conforming layer on the human head during rotational force impact while the outer shell layer is allowed to slide	
18	The helmet of claim 17, wherein the shear mechanism is a shear layer.	Ground 1 Ground 2 Ground 3 Ground 4 Ground 6
19	The helmet of claim 18, wherein the shear layer is connected to the outer shell layer through the first energy transformer, the first	Ground 1 Ground 2 Ground 3

Claim No.	Challenged Claim Language	Grounds for Finding Claim Invalid
	energy transformer operable to absorb energy from forces imparted onto the outer shell layer, wherein the first energy transformer includes a first absorptive/dissipative material to allow the outer shell layer to slide relative to the inner conforming layer.	Ground 4 Ground 6
20	The helmet of claim 19, wherein the inner conforming layer is connected to the shear layer, the inner conforming layer configured to conform to a human head, the inner conforming layer associated with a second energy transformer, the second energy transformer including a second absorptive/dissipative material, the second energy transformer operable to absorb energy from forces imparted onto the shear layer through the outer shell layer and the first energy transformer.	Ground 1 Ground 2 Ground 3