

Declaration of Dr. Charles F. Reinholtz – U.S. Patent No. 9,260,184

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SZ DJI TECHNOLOGY CO., LTD.,
Petitioner

v.

AUTEL ROBOTICS USA LLC,
Patent Owner

Case No. IPR2019-00846
Patent No. 9,260,184

DECLARATION OF DR. CHARLES F. REINHOLTZ

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I, Charles F. Reinholtz, declare as follows:

I. INTRODUCTION

1. I have been retained as an expert in this matter by counsel for Patent Owner Autel Robotics USA LLC (“Autel”). I have been asked to investigate and opine on the validity/patentability of claims of U.S. Patent No. 9,260,184 (“’184 patent”) (Ex. 1001) in the above captioned *inter partes* review (“IPR”), in view of the Petition filed by Petitioner SZ DJI Technology Co., Ltd. (“DJI”).

2. The ’184 patent is generally directed to a locking mechanism for rotor blades in an unmanned aerial vehicle (“UAV”). (Ex. 1001, ’184 patent at Abstract, claims.) I further understand that Autel owns the ’184 patent.

3. I understand that DJI petitioned for IPR of claims 3-4 of the ’184 patent and requests that the United States Patent and Trademark Office (“USPTO”) cancel claims 3-4 of the ’184 patent. I understand that the Patent Office instituted an IPR proceeding to review the patentability of claims 3-4 of the ’184 patent in IPR2019-000846.

4. I understand that Autel is filing a motion to substitute the following claims, respectively, for claims 3-4 in the ’184 patent:

- 12. The apparatus of claim 1 wherein the blade lock portion of the clockwise lock mechanism is configured to engage by partial

counterclockwise rotation with respect to the shaft lock portion thereof to releasably attach the clockwise rotor blade to the first driveshaft.

- 13. The apparatus of claim 12 wherein the counterclockwise lock mechanism comprises a shaft lock portion attached to the second driveshaft and a blade lock portion attached to the counterclockwise rotor blade, and the blade lock portion of the counterclockwise lock mechanism is configured to engage by partial clockwise rotation with respect to the shaft lock portion thereof to releasably attach the counterclockwise rotor blade to the second driveshaft.

I will refer to proposed claims 12 and 13 as the “Proposed Claims”.

5. I was asked to provide my opinion as to the patentability of the Proposed Claims in view of the prior art cited by DJI in its Petition.

6. In preparing this Declaration, I have reviewed the '184 patent and its prosecution history and considered the documents identified in Section IV in light of the general knowledge in the relevant art. In forming my opinions, I relied upon my education, knowledge, and experience and considered the level of ordinary skill in the art as discussed below.

II. BACKGROUND AND QUALIFICATIONS

7. I am currently a Professor at the Embry-Riddle Aeronautical University in the Department of Mechanical Engineering.

8. I earned a Bachelor of Science Degree (1976), a Master of Engineering Degree (1980), and a Ph.D. in Mechanical Engineering (1983) from the University of Florida. My Ph.D. research was in the field of optimization of spatial mechanisms.

9. From 1983 to present I have held a variety of professional and academic positions. From 1983-2007, I was an assistant professor (1983-1988), associate professor (1988-1993), professor (1993-1996), professor (1996-2002), and alumni distinguished professor (2002-2007) at Virginia Polytechnic Institute and State University. During that time, I also served as the W. S. White Chair for Innovation in Engineering Education (1996-1999) and Assistant Department Head of the Department of Mechanical Engineering (1996-2002). From 2007-present, I have been professor at Embry-Riddle Aeronautical University. During that time, I also served as the Chair of the Department of Mechanical Engineering at Embry-Riddle (2007-2017).

10. I am a member of numerous professional societies and organizations. For example, I have been a Fellow in the American Society of Mechanical Engineers (ASME) since 2003. That organization has recognized my work on a number of occasions, including with the award of the ASME Outstanding Faculty Advisor Award (1989-1990, 1991-92), the ASME National Faculty Advisor Award (1995), and the ASME Distinguished Service Award (2005).

11. For over 35 years, I have conducted research and taught classes in the field of mechanisms, mechanical design, robotics, robotics, and unmanned vehicle systems. My research in the robotics and unmanned systems area began in 1983, and I have remained continuously active in teaching and research in these areas through the present.

12. At Virginia Tech and Embry-Riddle Universities, I have taught a variety of courses, including Robotics, Advanced Robotics, Unmanned Systems, Mechanisms, Mechanical Design and Mechatronics and I have received several teaching awards such as the College of Engineering Certificate of Teaching Excellence (1987-88, 1997-98, 2001-02, 2006-07), Wine Award for Excellence in Teaching (1992), Virginia Tech Academy of Teaching Excellence (inducted 1992), Dean's Award for Excellence in Teaching (1998), Ingersoll-Rand Faculty Award for Outstanding Contributions to the Mechanical Engineering Department (2000), Outstanding Faculty Member Award (2003), and the Alumni Teaching Award (2004).

13. I have co-founded three successful companies working in the area of robotics and unmanned vehicle systems. I have also served as the advisor to many successful collegiate robotics teams, including the overall winning teams in the Association for Unmanned Vehicle Systems (AUVSI) Intelligent Ground Vehicle Competition (2003 through 2007), the International Aerial Robotics Competition

(2005, 2007), the Unmanned Aerial Systems Competition (2007), and the RoboBoat Competition (2014, 2015). I was also team lead for qualifying teams in the 2004 and 2005 DARPA Grand Challenge Competitions, and I was team lead and principal investigator of the third-place overall team in the 2007 DARPA Urban Challenge, a competition to develop a fully autonomous automobile capable of navigating a complex, dynamic urban course along with human-driven vehicles and other robotic cars.

14. I hold two U.S. patents and have authored a popular textbook and have over 125 publications related to the design and analysis of mechanisms, kinematics, manipulators, robotics, and aeronautics of unmanned systems. I have several best paper awards, such as the National Instruments Virtual Instrumentation Applications Best Control Paper Award for “Developing a Fully Autonomous Vehicle for Virginia Tech’s Entry in the DARPA Grand Challenge.” I have received many awards, including the Presidential Young Investigator Award from the National Science Foundation (1987-1992) and the South-Pointing Chariot Award at the 1999 Applied Mechanisms and Robotics Conference, for lifetime contributions to the mechanisms community.

15. Attached as Appendix A is a copy of my current curriculum vitae, which further sets out my academic and professional background and qualifications.

16. I am being compensated for my time in connection with this IPR at my standard consulting rate, which is \$400 per hour. My compensation is not dependent in any way upon the outcome of this matter.

III. RELEVANT LEGAL STANDARDS

A. Anticipation

17. I understand that a patent claim is unpatentable and invalid if the claim is anticipated. I understand that anticipation occurs when a single piece of prior art describes every element of the claimed invention, either expressly or inherently, arranged in the same way as in the claim. I understand that, for inherent anticipation, it is required that the missing descriptive material is necessarily present in the prior art.

B. Obviousness

18. I understand that a patent claim is unpatentable and invalid if the subject matter of the claim as a whole would have been obvious to a person of ordinary skill in the art at the time of the invention at issue. I understand that obviousness may be shown by considering more than one item of prior art. I understand that the following factors should be evaluated to determine whether the claimed subject matter is obvious: (1) the scope and content of the prior art; (2) the difference or differences, if any, between each claim of the patent and the prior art; and (3) the level of ordinary skill in the art at the time the patent was filed.

19. I understand that “objective indicia of non-obviousness,” also known as “secondary considerations,” are also to be considered when assessing obviousness if present including: commercial success; long-felt but unresolved needs; failure of others to solve the problem that the inventors solved; unexpected results; copying of the invention by others; and industry recognition or expressions of disbelief by experts in the field of the claimed invention. I understand that any of these factors provide objective evidence that a claimed invention was not obvious at the time of its invention. I also understand that objective indicia of non-obviousness must be commensurate in scope with the claimed subject matter. I also understand that there must be a nexus between the secondary considerations and the claimed invention.

20. I understand that the test of obviousness is whether the claimed invention, as a whole, would have been obvious to one of ordinary skill in the art as of the date of the invention in light of the prior art.

21. I understand that a claim is not proved obvious merely by demonstrating that each of the elements was independently known in the prior art. I understand that most, if not all, inventions rely on building blocks long since uncovered, and claimed discoveries, almost of necessity will likely be combinations of what is already known. I understand that it is important to identify whether a reason existed at the time of the invention that would have prompted a person of ordinary skill in the art in the relevant field to combine the known elements in the

way the claimed invention does. I understand that the use of hindsight must be avoided when considering whether the alleged invention would have been obvious to the person of ordinary skill in the art. In assessing obviousness, I have been instructed to consider the distortion caused by hindsight bias, guard against slipping into the use of hindsight, be cautious of arguments that rely upon after-the-fact reasoning, and avoid the temptation to read into the prior art the teachings of the invention in issue.

IV. DOCUMENTS

22. I have referenced and/or reviewed the following documents in connection with this Declaration: (1) the '184 patent and prosecution history, (2) the Petition filed by DJI and the exhibits cited therein, (3) the Institution Decision and (4) any additional documents cited herein.

V. SUMMARY OF OPINIONS

23. It is my opinion, as set forth in detail in this declaration, that the Proposed Claims are patentable in view of the prior art cited by DJI in their IPR Petition.

VI. BACKGROUND REGARDING STATE OF THE ART

A. Description of the Relevant Art

24. Patent Owner and Petitioner both sell unmanned aerial vehicles (“UAVs”) that are used for aerial photography and videography, in addition to use in fields such as agriculture. These UAVs include quadcopters consisting of a body

with multiple arms, each with a rotor and rotor blade¹ attached at the distal end, extending from the body. Of the rotors, half spin clockwise and half spin counterclockwise so as to negate the torque produced by each rotor, which would otherwise result in the UAV spinning in circles about the axis of lift. To generate positive vertical lift on all four rotors, the clockwise spinning rotors must also have blades with the opposite pitch of the blades on the counterclockwise spinning rotors. Accordingly, in the event that a blade is misplaced on the wrong rotor (e.g., a clockwise blade attached to a counterclockwise rotor), the lift force on that rotor will be reversed, creating a downward thrust force. This is often a catastrophic mistake that will cause damage to the UAV and will potentially endanger bystanders.

25. An image of Autel's EVO product is reproduced below:



Figure 1. Autel's EVO

¹ Rotor blades of a UAV are sometimes referred to as propellers, props, blades, or rotors.

26. Most of the UAVs produced by Autel and DJI are quadcopters with a video camera attached via gimbal to the bottom of the UAV. This allows the UAVs to act as flying cameras, getting into positions and capturing angles on film that previously had to be accomplished by using manned aircraft.

27. It can be desirable for a UAV to have removable rotor blades. UAVs with removable rotor blades are easier to store. In addition, the blades of UAVs can be damaged during flight. It is cheaper and faster to replace a damaged blade that is easily removable from the UAV. Removable blades thus require a mechanism for attaching the rotor to the UAV motor so that the blades will function by spinning in the direction of the motor shaft and generating the lift required to fly the UAV. It is desirable to have an attachment mechanism that securely attaches the blade to the UAV motor, but also allows a user to quickly and easily attach and detach the blades from the UAV.

B. Description of a Person of Ordinary Skill in the Art

28. It is my opinion that a person of ordinary skill in the art “POSA” at the time of the invention of the ’184 patent would have had a bachelor’s degree in mechanical engineering and at least two years of experience designing mechanisms and mechanical structures of the type used in releasable couplings and locking devices. Additional education could substitute for professional experience and significant work experience could substitute for formal education.

29. Dr. Ducharme opines that a POSA “would have had at least an undergraduate degree in mechanical engineering, or equivalent education, training, or experience, with at least two years of experience with UAVs.” Ex. 1003 at ¶ 72.

30. I have reviewed the Claim Construction Order issued by the Chief Administrative Law Judge in Investigation No. 337-TA-1133, which includes a definition of a POSA. Ex. 2004 at 6 (“a person of ordinary skill in the art with respect to the ’184 patent would have at least (1) a Bachelor’s degree in mechanical engineering, or equivalent education, training, or experience, and (2) at least two years of experience with rotary apparatuses, including rotary aircraft apparatus and UAVs, or equivalent experience.”) I do not view this definition or Dr. Ducharme’s proposed definition as substantially different from mine, and my opinions stated herein would remain the same regardless of whether my, Dr. Ducharme’s, or the ITC’s POSA definition were applied.

31. I understand that, for purposes of this Report, the time of invention of the ’184 Patent is assumed to be May 15, 2013 (i.e., the priority date) for the ’184 patent. For the purposes of my analysis, I have used May 15, 2013 as the relevant date.

VII. THE '184 PATENT

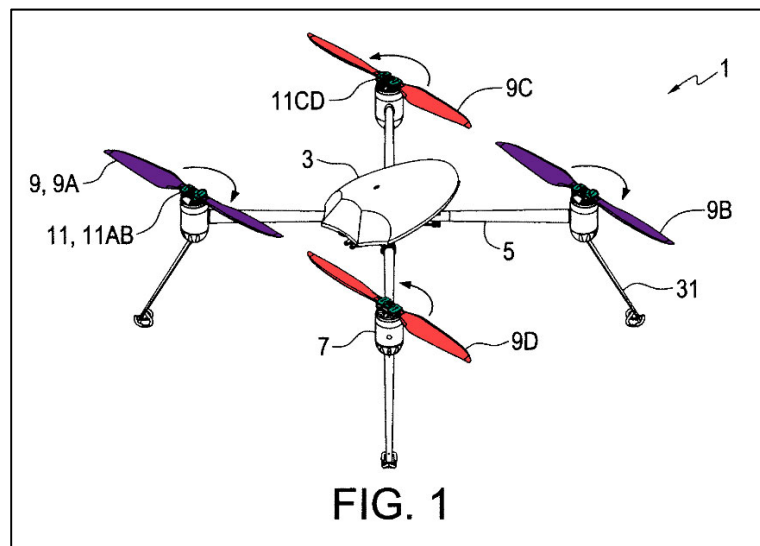
A. Background and Description of the '184 Patent

32. U.S. Patent No. 9,260,184 (the '184 Patent) was issued on February 16, 2016 and is entitled “Compact Unmanned Rotary Aircraft.” Ex. 1001. It was originally assigned to Draganfly Innovations Inc., which, in turn, assigned the patent to Autel. The '184 Patent claims priority to a foreign application filed on May 15, 2013.

33. The '184 patent is generally directed to a multi-rotor unmanned aerial vehicle (UAV) with a rotor assembly on each arm wherein the rotor blades rotate in opposite directions to avoid exerting torque on the body which would otherwise cause it to spin. Ex. 1001, '184 Patent, 1:18-23. One of the innovations claimed in the '184 Patent is a UAV with rotor blades that can be removably coupled to the UAV through a clockwise/counterclockwise locking mechanism that only allows the correct blade to be attached to the corresponding electric motor of the UAV. This allows the rotor blades configured to spin clockwise to only be able to lock to the motors configured to spin clockwise, and allows the rotor blades configured to spin counterclockwise to only be able to lock to the motors configured to spin counterclockwise. Ex. 1001, '184 Patent, 1:55-2:7. As a result of this innovation, the rotor blades of the multi-rotor UAV “can be easily detached for transport o[r]

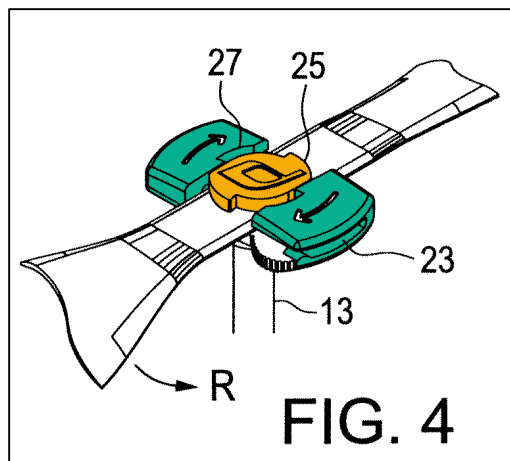
storage, and cannot be placed on driveshafts rotating the wrong direction.” Ex. 1001, '184 Patent, 2:16-18.

34. Figure 1 of the '184 Patent illustrates an embodiment on the invention claimed—i.e., a quadcopter with two clockwise rotors blades (purple) and two counterclockwise blades (red).

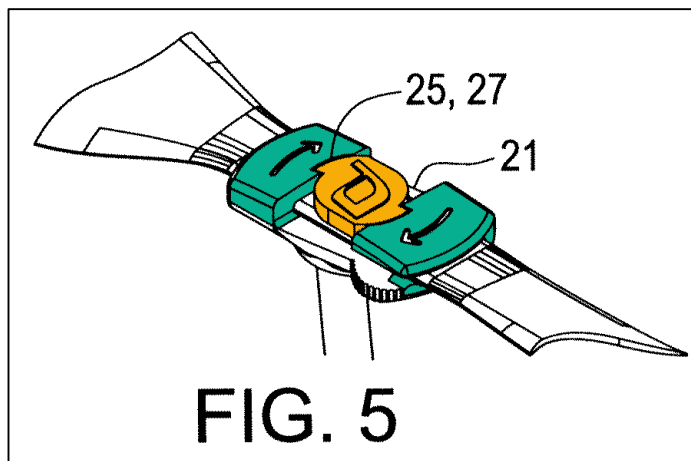


'184 Patent, Fig. 1

35. Figures 4-10 illustrate an example of the claimed lock mechanisms in more detail. Figure 4, for example, shows the clockwise lock mechanism used to attach clockwise rotor blades in the embodiment in Figure 1, with the rotor blade in the recess ready for engagement or removal (i.e., unlocked). Figure 5 illustrates that same clockwise lock mechanism, but with the rotor blade engaged and locked.



'184 Patent, Fig. 4 (Highlighted)



'184 Patent, Fig. 5 (Highlighted)

36. With reference to these figures, the clockwise rotor blade is dropped into the recess 21 in Figure 4 and then rotated in direction R opposite to the direction of the arrows that indicate the direction of rotor rotation such that the lugs 25 on the rotor blade engage the notches 27 on the drive shaft. Ex. 1001 at 3:63-4:18.

37. As can be seen with reference to the above figures and the description in the patent of how a user attaches a rotor blade using the lock mechanism of the '184 Patent, a user attaches the rotor blade by rotating the blade about the axis of the driveshaft by a fraction of a revolution. Ex. 1001 at 3:63-4:40. The patent specification describes and depicts how (1) the blade lock portion of the clockwise lock mechanism is configured to engage by partial counterclockwise rotation with respect to the shaft lock portion thereof to releasably attach the clockwise rotor blade to the first driveshaft and (2) the blade lock portion of the counterclockwise lock mechanism is configured to engage by partial clockwise rotation with respect to the

shaft lock portion thereof to releasably attach the counterclockwise rotor blade to the second driveshaft. Ex. 1001 at 3:63-4:40; Figures 4-5, 9-10. This type of lock mechanism, which I will refer to as a “twist lock” mechanism, allows a user to quickly and conveniently attach a rotor blade to a drive shaft. As explained more fully herein, this twist lock mechanism is different than, and an improvement over, traditional thread and nut connection mechanisms that require a user to rotate the rotor blade for multiple full revolutions in order to attach it to the drive shaft. Traditional thread and nut connection mechanisms also have an over-tightening problem, where the torques generated during flight make the rotor blade difficult to remove from the motor.

B. The '184 Patent Claims

38. As described above, I have been asked to investigate the validity/patentability of proposed claims 12 and 13. Claim 1 is an independent claim. Claims 12 and 13 are dependent claims that depend, directly or indirectly, from claim 1.

39. Claims 1, 12 and 13 are reproduced below:

1. A rotary wing aircraft apparatus comprising:

a body;

a plurality of arms extending laterally from the body, and a rotor assembly attached to an outside end of each arm;

each rotor assembly comprising a rotor blade releasably attached to a driveshaft by

a lock mechanism, and a drive rotating the driveshaft;

wherein a first driveshaft rotates in a clockwise direction and a second driveshaft rotates in a counterclockwise direction;

wherein a clockwise rotor blade is releasably attached to the first driveshaft by engagement in a clockwise lock mechanism and generates a vertical lift force when rotated in the clockwise direction, and

a counterclockwise rotor blade is releasably attached to the second driveshaft by engagement in a counterclockwise lock mechanism and generates a vertical lift force when rotated in the counterclockwise direction;

wherein the clockwise rotor blade is engageable only with the clockwise lock mechanism and cannot be engaged in the counterclockwise lock mechanism, and the counterclockwise rotor blade is engageable only with the counterclockwise lock mechanism and cannot be engaged in the clockwise lock mechanism; and

wherein the clockwise lock mechanism comprises a shaft lock portion attached to the first driveshaft and a blade lock portion attached to the clockwise rotor blade, the shaft lock portion defining notches configured to engage corresponding lugs on the blade lock portion.

12. The apparatus of claim 1 wherein the blade lock portion of the clockwise lock mechanism is configured to engage by partial counterclockwise rotation with respect to the shaft lock portion thereof to releasably attach the clockwise rotor blade to the first driveshaft.

13. The apparatus of claim 12 wherein the counterclockwise lock mechanism comprises a shaft lock portion attached to the second driveshaft and a blade lock portion attached to the counterclockwise rotor blade, and wherein the blade lock portion of the counterclockwise lock mechanism is configured to engage by partial clockwise rotation with respect to the shaft lock portion thereof to releasably attach the counterclockwise rotor blade to the second driveshaft.

C. Claim Construction

40. I have been asked to review the claims, and ascertain the meaning of the claims, from the perspective of a person of ordinary skill in the art at the time of the invention. Unless otherwise set forth herein, I have accorded the claim language its plain and ordinary meaning to a person of ordinary skill at the time of the invention.

41. I have been informed that in this IPR proceeding the claims are to be given their plain and ordinary meaning as understood by a POSA at the time of the invention in light of relevant intrinsic (patent specification and file history) and extrinsic evidence. Accordingly, I have applied that claim construction standard in my analysis herein.

1. **“the clockwise rotor blade is engageable only with the clockwise lock mechanism and cannot be engaged in the counterclockwise lock mechanism, and the counterclockwise rotor blade is engageable only with the counterclockwise lock mechanism and cannot be engaged in the clockwise lock mechanism”**

42. Claim 1 of the ‘184 Patent requires that “the clockwise rotor blade is engageable only with the clockwise lock mechanism and cannot be engaged in the counterclockwise lock mechanism, and the counterclockwise rotor blade is engageable only with the counterclockwise lock mechanism and cannot be engaged in the clockwise lock mechanism.”

43. I will refer to the above limitation as the “Engagement Limitation”. This limitation means that a clockwise rotor blade cannot be attached to a counterclockwise driveshaft and vice versa.

44. As mentioned previously in ¶ 24, if a UAV user attaches the wrong blade to the wrong driveshaft, the UAV will not function properly and could be damaged or dangerous. The ‘184 patent, after stating that “[t]he clockwise rotor blade is engageable only with the clockwise lock mechanism and cannot be engaged in the counterclockwise lock mechanism”, explicitly states that the claimed rotor blades cannot be attached to the wrong driveshaft. Ex. 1001, at 2:2-18 (“The rotor blades can be easily detached for transport o[r] storage, and cannot be placed on driveshafts rotating the wrong direction.”) (emphasis added). The purpose and advantage of this aspect of the invention is the prevention of the malfunctioning and potential damage that could occur if a user were to try to fly a UAV with a misplaced blade. Accordingly, a POSA would understand the engagement limitation to mean that a user is unable to attach the wrong blade to the wrong driveshaft.

VIII. SUMMARY OF THE ALLEGED INVALIDATING PRIOR ART

A. Sasaki

45. Sasaki relates to a propeller for a flying toy. Ex. 1006, Sasaki at 1:30-32. Sasaki begins with a description of a prior art design, shown in Figures 8 and 9, and an explanation of the drawbacks of the design. Sasaki at 1:33-2:28.

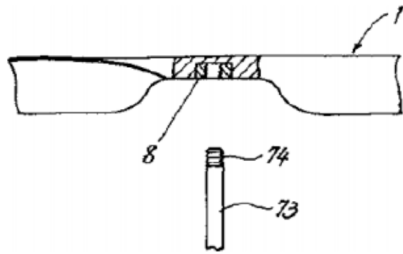


Fig. 8

46. The design in Figure 8 includes a simple mechanism for attaching the prop to the driveshaft. The central portion of the prop includes a threaded nut that screws onto the driveshaft, which is threaded at the distal end. Sasaki at 1:49-2:4. Sasaki explains that in a design of this type, it is necessary to ensure that a propeller that rotates to the right uses a left-hand-threaded nut and a propeller that rotates to the left utilizes a right-hand-threaded nut. Sasaki at 2:5-16. In such an arrangement, during use, the directional force caused by rotation of the prop will have a tightening effect. *Id.* If the screws were reversed, the directional force would have a loosening effect, which would be an untenable design due to the danger of a prop releasing. Sasaki makes no mention that the purpose of such a design is to prevent accidental misplacement of the propeller blades (e.g., a clockwise prop on a counterclockwise driveshaft), and there is no disclosure in Sasaki indicating the need or motivation for such a design.

47. One drawback of the screw-on type blade attachment mechanism described in Sasaki is that a user must rotate the blade several full revolutions in order to tighten and attach the blade to the driveshaft and ensure that a sufficient

number of threads are engaged to create a mechanically secure connection. Installing a blade in this fashion is time consuming and cumbersome, particularly since UAV users typically remove blades for storage of the UAV, and thus remove and install blades frequently. Sasaki does not mention a desire or motivation to overcome this drawback.

48. Sasaki explains that a drawback of the screw-on prior art design, where the rotating shaft exerts a tightening force on the prop and shaft connection, is that the connections become tightened more than necessary, and the props are difficult to remove and replace. Sasaki at 2:9-16. Accordingly, in addition to having a cumbersome process for installing a prop by screwing it on to the driveshaft, the design makes it difficult to remove a prop.

49. Sasaki explains that its invention overcomes the overtightening problem by using a mechanism for attaching the prop to the shaft that is not dependent on the direction in which the prop rotates. Sasaki at 2:24-28 (“In addition, the present invention is intended to define a fixture of a propeller which can easily be attached to and detached from a rotating shaft without depending on the direction of rotation of the propeller.”). Not only is there no disclosure in Sasaki that indicates a need, motivation, or desire to utilize lock mechanisms for the prop and driveshaft that depend on the rotational direction of the prop, there is an express teaching to utilize a design that is not dependent on the direction in which the prop rotates.

50. The design of the connection mechanism between the prop and driveshaft in the embodiment in Sasaki, illustrated in Figures 1 and 2 below, is independent of the direction of the prop rotation. Sasaki at 5:31-7:28.

51. With reference to the figures, Sasaki explains that a second locking member (6) is affixed to the driveshaft. Sasaki at 6:48-50. Claws from a first locking member (5) engage with the second locking member to attach the prop to the driveshaft. Sasaki at 7:2-7. As can be seen from the figures, the design of the first and second locking members are independent of the rotation direction of the prop, and the same design is used for all props and driveshafts on the flying toy. Accordingly, the lock mechanism of the embodiment described in Sasaki is not dependent on the directional rotation of the propeller. In addition, the lock mechanism of the embodiment described in Sasaki does not require a user to rotate the rotor blade in relation to a driveshaft in order to attach the rotor blade to the UAV.

52. The screw-on type blade attachment mechanism described in Sasaki does not prevent a rotor blade from being attached to the wrong driveshaft (e.g., a clockwise blade being attached to a counterclockwise spinning driveshaft and vice versa). Based on my own experience with screw-on type blade attachment mechanisms, I know that a left-threaded blade, for example, can be attached to a right-threaded driveshaft. As a practical matter, multirotor UAVs typically use

plastic or composite propellers for both the clockwise and counterclockwise blades. Because this material is soft and the driveshafts are much harder metal, it is relatively easy to thread a clockwise rotor blade on a motor shaft intended for a counterclockwise blade, and vice versa.

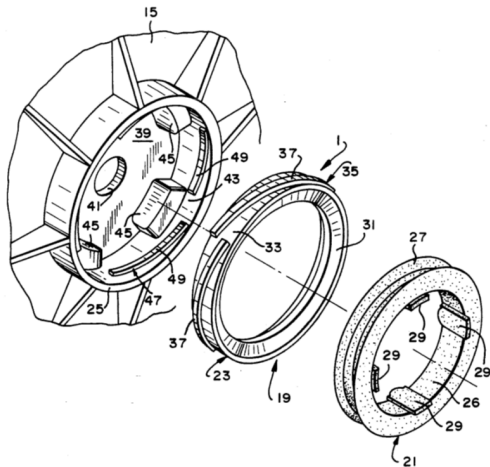
53. In the hearing for an ITC case between Petitioner and Autel that involved the '184 patent, I witnessed counsel for Autel question an expert for DJI regarding one of DJI's own UAV's (known as a Phantom 3) that utilizes the screw-on type connection mechanism described in Sasaki. Ex. 2005 at 332:23-335:8. While questioning the expert, counsel for Autel was able to easily screw a rotor blade on the wrong driveshaft. Ex. 2005 at 335:9-337:20. When counsel held the UAV upside down, the rotor blade remained attached, and when counsel rotated the drive with his finger, the blade rotated along with the drive. Ex. 2005 at 337:1-20.

54. Exhibit 2006 is a video that I created to demonstrate that rotor blades can be installed on the wrong drives on UAVs that utilize the conventional screw-on design described in Sasaki. The video depicts me attaching rotor blades on a DJI Phantom 3 drone, the same model drone referenced in the preceding paragraph. Also, attached to this declaration as Appendix B is a document that contains several screenshots from the video of Exhibit 2006. On the Phantom 3, clockwise rotor blades are designated with a black hub tip and counterclockwise rotor blades are designated with a silver hub tip. Likewise, the clockwise driveshafts have black tips

and the counterclockwise driveshafts have silver tips. In the video, and as shown in the screenshots in Appendix B, first I correctly install a counterclockwise blade and then a clockwise blade by rotating them about the respective driveshafts (see screenshots B and C in Appendix B). Next, I incorrectly install a clockwise and counterclockwise blade by rotating them about the respective driveshafts (see screenshots D and E in Appendix B). Finally, I hold the drone upside down to show that the blades do not fall off (shown at 0:58 of the video) and then lift the drone in the air by the rotor blades and shake it to show that the rotor blades are securely attached. See Ex. 2006 at 1:06-1:27; Appendix B at screenshot F.

B. Sokn

55. Sokn is directed to a motor mount assembly for a clothes dryer. It states, “An electric fan motor of a domestic clothes dryer is directly mounted to an associated plastic fan housing... to provide a precise alignment between the motor and the housing.” Ex. 1007, Sokn at Abstract. Sokn is not related to UAVs or UAV design and does not address mounting a rotating blade or member to a drive motor. The embodiment in Sokn, shown below, is an assembly for mounting an electric motor to a fan housing. Sokn at 1:45-48.



56. The mounting system disclosed in Sokn is not used to mount the fan itself to the drive motor. Rather, it is used to mount the fan motor to the housing that contains the fan in a clothes dryer, “More particularly, the invention relates to an improved assembly for mounting a fan motor to the fan housing of a domestic clothes dryer.” Sokn at 1:9-11. The housing of the clothes dryer is a fixed, non-rotating structure. Sokn does not provide details of how the actual fan is attached to the shaft 7 of the drive motor. The only related disclosure in Sokn notes, “This alignment permits a fan blade mounted on the end of shaft 7 to rotate freely within housing 15 and avoid impact therewith during operation of motor” Sokn at 5:4-7. Sokn goes on to suggest broader uses of the invention, but they only relate to mounting a fan motor to a fixed housing, “Though the invention has been described as being utilized in the fan system of a domestic clothes dryer, it is of course understood that the invention may also be utilized in any other similar environment

wherein a precise alignment between a motor and an associated housing is desired”
Sokn at 5:10-15.

57. Since Sokn is directed at a mounting system for connecting a motor to a fixed housing, there is no consideration in Sokn for creating an attachment mechanism where rotor blades can be easily detached for transport or storage. It is likely that the clothes dryer fan blade mounting solution provided by Sokn will never need to be disassembled or transported by a user, and there is no discussion in Sokn regarding disassembly. Furthermore, there is no discussion in Sokn regarding clockwise or counterclockwise rotation, nor is there any discussion about preventing mounting to a shaft rotating in the wrong direction. Since Sokn’s fan (and centrifugal blowers in general) do not use rotor blades, there is obviously no consideration in Sokn of clockwise or counterclockwise rotating rotor blades. Sokn’s disclosure has no information on and no reason to address the critical need to prevent interchangeably mounting such blades. Sokn does not depict different configurations for its lock mechanism to accommodate the proper fitting of components based on the direction of rotation.

IX. THE PROPOSED CLAIMS ARE PATENTABLE OVER SASAKI AND SOKN

58. In my opinion, the Proposed Claims of the ’184 patent are patentable over Sasaki and Sokn.

59. As previously stated in paragraphs 42-44, the Engagement Limitation of Claim 1 requires that the lock mechanism prevent the attachment of a rotor blade to the wrong driveshaft. As explained previously in paragraphs 52-54, the prior art screw-on type design disclosed in Sasaki does not prevent a blade from being attached to the wrong driveshaft. Also as previously explained in paragraphs 49-51 of this declaration, the embodiment disclosed in Sasaki is not dependent on the directional rotation of the propeller, and thus, does not meet the Engagement Limitation. Indeed, as explained in paragraphs 48-49 of this declaration, Sasaki criticizes the screw-on prior art design illustrated in Figure 8, and indicates that a goal of the invention is to overcome the problems of the prior art design by using a mechanism that is not specific to the direction of rotation of the rotor blades. Thus, Sasaki teaches away from directionally specific lock mechanisms.

60. Proposed claim 12 requires that the “blade lock portion of the clockwise lock mechanism is configured to engage by partial counterclockwise rotation with respect to the shaft lock portion thereof to releasably attach the clockwise rotor blade to the first driveshaft.” Proposed claim 13 requires that the “blade lock portion of the counterclockwise lock mechanism is configured to engage by partial clockwise rotation with respect to the shaft lock portion thereof to releasably attach the counterclockwise rotor blade to the second driveshaft.” Sasaki does not disclose these limitations because, as previously described in paragraphs 47 and 51, (1) the

prior art screw-on type connection mechanism described in Sasaki requires a user to rotate the blade for several full revolutions in order to attach the blade to the driveshaft and (2) the embodiment described in Sasaki does not require rotation of the rotor blade with respect to a driveshaft in order to attach the blade.

61. Sokn relates to a clothes dryer, not a UAV. Sokn does not disclose clockwise and counterclockwise rotating driveshafts, clockwise and counterclockwise rotating blades, clockwise and counterclockwise lock mechanisms, rotor blades that generate a vertical lift force, or lock mechanisms that prevent a rotor blade from being attached to the wrong drive. Accordingly, Sokn does not disclose numerous limitations of claim 1 and Proposed Claims 12 and 13.

62. In my opinion, a POSA would not be motivated to combine Sasaki with Sokn. As previously explained, Sasaki fails to disclose the convenient twist-lock feature of the '184 Patent, and fails to disclose a blade lock mechanism that prevents attachment of the wrong blade. Sasaki itself does not describe any motivation to obtain these features. As previously explained, Sasaki was concerned with solving the problem of overtightening, and it explicitly indicates that it solved the problem by utilizing a blade connection mechanism that did not depend on direction of rotation. Accordingly, in my opinion, a POSA would not be motivated to modify Sasaki to obtain the twist-lock and mistake-proof features of the '184 Patent.

63. Even if, however, there were a motivation to modify Sasaki, a POSA would not be motivated to use Sokn to achieve the claimed inventions of the ‘184 Patent. Sasaki and Sokn are from two substantially different fields. A POSA would not look to clothes dryer art when designing a flying vehicle. The design considerations and problems faced by a UAV designer are substantially different than for a clothes dryer. Convenient, fool-proof assembly and disassembly of rotor blades is a critical aspect of the ‘184 patent. Sokn discusses only assembly and does not mention disassembly, nor is there any mention of rotational direction. As noted in Sokn, “[T]he invention relates to an improved assembly for mounting a fan motor to the fan housing of a domestic clothes dryer.” Sokn 1:9-12. The solution presented by Sokn is concerned with accurate assembly of the motor to the housing to allow minimum clearance between the fan blades and the fan housing, “maximum efficiency of fan operation requires a minimum clearance between the periphery of the fan blade and the adjacent interior wall portions of the housing.” Sokn 1:37-40. Precise alignment is important to the application described by Sokn, where a blower is positioned with a housing. Tight clearances improve efficiency, but it would not be acceptable to allow the blower or fan blade to touch the housing. Nowhere in the patent does Sokn mention the direction of rotation being a consideration in the mounting of an electric fan motor to an associated fan housing. This is much different than mounting rotor blades on a rotary wing aircraft, where the direction of

rotation is critical, but where clearance between the rotor blade and a fan housing is not a consideration. There is no consideration in Sokn for creating an attachment mechanism such that rotor blades can be easily detached for transport of storage and cannot be placed on driveshafts rotating the wrong direction. It is likely that the clothes dryer fan blade mounting solution provided by Sokn will never need to be disassembled or transported by a user. There is no discussion in Sokn regarding clockwise and counterclockwise rotating rotor blades or the critical need to prevent interchangeably mounting such blades in a rotorcraft. As such, Sokn does not depict or discuss different configurations for its lock mechanism to accommodate the proper fitting of components based on the direction of rotation. Accordingly, a POSA would not look to Sokn for a convenient mechanism for releasably detaching UAV rotor blades, or for directionally specific lock mechanisms that prevent mis-installation of blades based on the direction of rotation.

64. Petitioner implies that Sokn teaches clockwise and counterclockwise engagement mechanisms. Petition at p. 34 (“Based on this explicit teaching of Sokn and the teachings of Sasaki regarding directionality of threading in the clockwise and counterclockwise coupling mechanisms, ...”). In my opinion, any suggestion that Sokn teaches clockwise and counterclockwise engagement mechanisms is incorrect. In both embodiments in Sokn, the motor assembly, including ring 19 in the first embodiment and ring 111 in the second embodiment, is rotated clockwise

(i.e., the same way as a convention right-hand screw) to tighten it into the dryer housing. See Sokn at Figures 3 and 5. There is no discussion in Sokn regarding the direction of rotation or the relevance of clockwise versus counterclockwise rotation when installing a centrifugal fan motor to a housing.

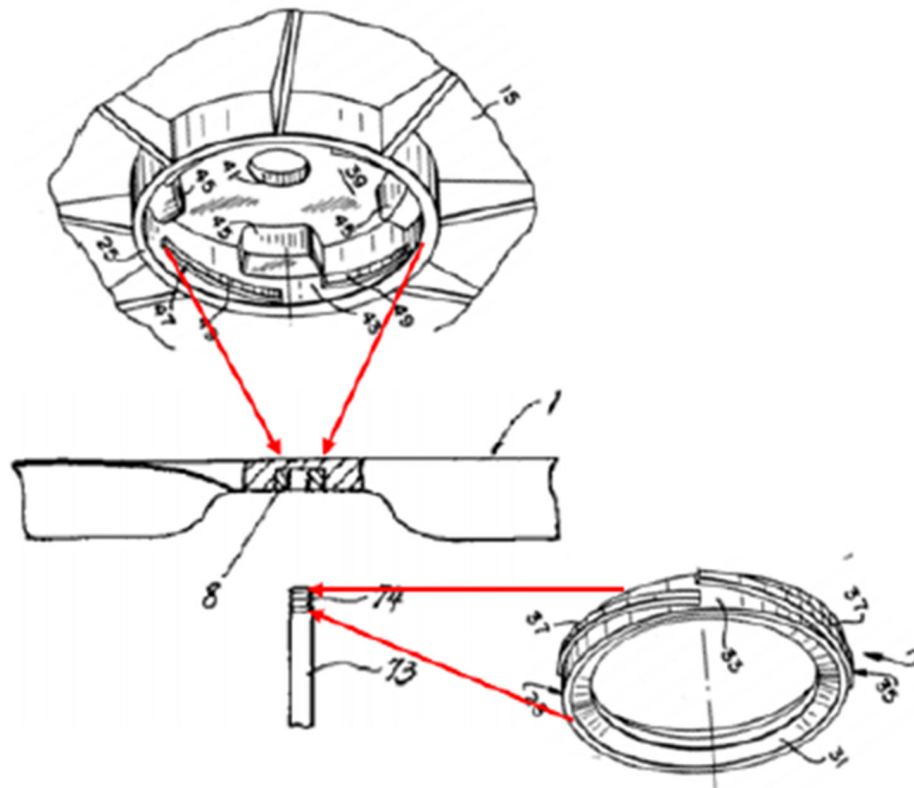
65. Petitioner's incorrect understanding appears to be based on Sokn's discussion of the importance of achieving precise alignment between components. Dr. Ducharme cites to Sokn at 3:66-4:2 and notes that, "Sokn further teaches that the first and second engagement portions and stop members can be configured to provide a predetermined orientation for engagement and interlock connection." Ex. 1003 at ¶ 109. Dr. Ducharme appears to conclude that this teaches clockwise and counterclockwise coupling mechanisms. However, reading slightly further in Sokn, it is clear that providing a predetermined orientation is referring to the accurate alignment of components and not to a clockwise and counterclockwise assembly direction, "It is of course possible to configure engagement portions 35 and 47, and also stop members 45, in order to provide a predetermined orientation for the engagement and interlock connection between ring assembly 19 and socket 24, and also an interference fit therebetween for further assuring precise alignment and a secure direct attachment of motor 3 to housing 15. Sokn 3:66-4:4. This understanding is also supported by the abstract (Sokn, Abstract) ("An electric fan motor of a domestic clothes dryer is directly mounted to an associated plastic fan

housing through an interlocking connection between a composite mounting ring of the motor and a cylindrical socket integrally formed with the housing to provide a precise alignment between the motor and the housing.”), and in the broader description of the possible applications of the invention, (Sokn: 5:10-24) (“Though the invention has been described as being utilized in the fan system of a domestic clothes dryer, it is of course understood that the invention may also be utilized in any other similar environment wherein a precise alignment between a motor and an associated housing is desired. For example, heating, ventilation and air conditioning systems may clearly utilize the invention to distinct advantage in order to realize a minimum clearance between the periphery of a blower or fan blade and the internal adjacent wall portions of the housing in order to achieve maximum operating efficiency. Thus, the invention resides in an improved motor mount assembly which permits a direct and secure attachment of a motor to an associated housing in order to realize a precise alignment therebetween.”)

66. I note that this precise alignment is important to the applications described by Sokn, where a blower is positioned with a housing. Tight clearances improve efficiency, but it would not be acceptable to allow the rotating blower to touch the housing. Nowhere in the patent does Sokn mention the direction of rotation being a consideration in the mounting of an electric fan motor to an associated fan housing. This is much different than mounting rotor blades on a rotary

wing aircraft, where the direction of rotation is critical, but where clearance between the rotor blade and a housing is not a consideration.

67. In addition, Petitioner incorrectly asserts that its proposed combination of Sasaki and Sokn will solve the overtightening problem described in Sasaki. Petition at 35; Ex. 1003 at ¶ 109. But in attempting to modify Sasaki based on Sokn, Petitioners arrive at the same basic self-tightening screw and nut combination that Sasaki is teaching away from. As shown in Petitioner's Figure below, Sokn's dryer fan housing 15 includes a cylindrical socket 25 with thread segments 49. These thread segments engage with corresponding thread segments 37 on ring 19 that is attached to the motor housing through resilient ring member 21. The motor (via threads 37 on ring 19) is rotated into engagement with threads 49 on socket 25 until the face of ring 19 abuts the faces of stop members 45 on socket 25. The figure below shows petitioner's proposed substitution of elements of Sokn into Sasaki with the red arrows showing the proposed substitution.



68. The proposed combination eliminates the advantageous aspects of Sokn (the large diameter, widely spaced mating features that contribute to precise alignment, Sokn 3:53-57), but it retains the critical problems that Sasaki is attempting to solve, namely the self-tightening and easily over-tightened nature of a threaded connection. Petitioners contend that, “The stops prevent overtightening by restricting further rotation.” Petition page 35; Ex. 1003 at ¶ 109. This is incorrect. The interaction of the stops 45 and the face of ring 19 is just like threading a lid onto a jar. As the closed end of the lid (stops 45) contacts the top of the jar (face of ring 19), further rotation becomes more difficult, but this does not prevent the lid from being overtightened. As noted in Sokn when discussing the installed position, “In

this position, ring assembly 19 is disposed in abutting engagement against stop members 45, thus assuring a secure attachment between ring assembly 19 and socket 25 which will not become accidentally loosened or disconnected during operation of motor 3.” Sokn at 3:60-65. Sokn never suggests that this arrangement can or will prevent overtightening. In the applications envisioned by Sokn, installation torque can be accurately set to assure a secure connection.

69. In Petitioner’s proposed substitution, the face of Sokn’s ring assembly 19 simply becomes the distal end face of the driveshaft 73 in Sasaki. The face of ring 19 is abutting the stops 45 just as the end of Sasaki’s drive shaft would abut the closed (blind) end of nut 8. Petitioner’s proposed substitutions simply replace the continuous shaft threading 73 of Sasaki with the segmented threads and they replace the closed end (blind face) of Sasaki’s nut 8 with the segmented face of stops 45. But just like the analogous jar and lid example mentioned above, cylindrical socket 25 and ring 19 can be overtightened. The combination does not solve the overtightening problem. This is still a threaded connection where the end of the drive shaft will tighten against the closed end of the nut due to normal operational rotor torques.

70. In my opinion, and based on my experience, the mistake-proof feature of the ‘184 patent that prevents incorrect attachment of a rotor blade and the twist-lock feature of the ‘184 patent that utilizes partial rotation of the blade for convenient

and quick attachment of a rotor blade, are two substantial and unique improvements over prior art attachment mechanisms. Drone users typically attach and remove blades with every use of the drone, and therefore prefer fast and convenient mechanisms for blade attachment. Also, in my experience, it is relatively easy for drone users to mis-install rotor blades. Incorrectly installing a rotor blade, even on a single occasion, can be a major concern because when a user tries to operate the drone, instead of creating lift, the mis-installed blade will create a downward force. This can lead to damage of the aircraft or injury to anyone nearby.

71. For at least the aforementioned reasons, it is my opinion that the Proposed Claims are patentable over Sasaki and Sokn. I understand that Petitioner will have an opportunity to raise patentability arguments with respect to the Proposed Claims after Autel has filed its motion to amend claims 3 and 4. I reserve my rights to respond to any such arguments after they are made, including additional reasons why Sasaki and Sokn do not render the Proposed Claims unpatentable.

X. CONCLUSION

72. I hereby 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.

Declaration of Dr. Charles F. Reinholtz – U.S. Patent No. 9,260,184

Date: 10 January 2020

A handwritten signature in black ink, appearing to read 'C. F. Reinholtz', is written over a horizontal line.

APPENDIX A

CHARLES F. REINHOLTZ, Ph.D.

Education

Doctor of Philosophy, University of Florida, Mechanical Engineering, 1983
Master of Engineering, University of Florida, 1980
Bachelor of Science, University of Florida, 1976

Full-time Industrial Experience

1978, Burroughs Corporation, Orlando, Florida, Design Engineer, Non-impact Printing Group
1989-1996 Milliken and Company, Spartanburg, South Carolina, summer employment and consulting involving textile equipment design

Academic Employment Experience

Virginia Polytechnic Institute and State University, Blacksburg, Virginia
Assistant Professor, September 1983 to August 1988, Tenure Granted
Associate Professor, August 1988 to August 1993
Professor, August 1993
W. S. White Chair for Innovation in Engineering Education, Aug. 1996 to Aug. 1999
Assistant Department Head and ABET Review Chair, 1996-2002
Alumni Distinguished Professor, 2002-2007
Embry-Riddle Aeronautical University, Daytona Beach, Florida
Professor and Chair, Department of Mechanical Engineering, 2007-2017
Professor, Department of Mechanical Engineering, 2017-

Membership in Professional Organizations and Honor Societies

<u>Society</u>	<u>Membership Grade</u>
ASME	Fellow
SAE	Member
American Nuclear Society	Member 1995-1997
Tau Beta Pi	Member
Pi Tau Sigma	Member
Sigma Xi	Member
Epsilon Lambda Chi	Member
ASEE	Member, 1984-1987, 1998-99
AUVSI	Member

Professional Honors and Awards

Benton Engineering Council Service Key, University of Florida, 1976-1977.
Procter and Gamble Best Paper Award, 9th Applied Mechanisms Conference, October, 1985.
Presidential Young Investigator Award, 1987-1992, National Science Foundation
Certificate of Teaching Excellence, Virginia Polytechnic Institute and State University, 1987-88, 1997-98 and 2001-02.

ASME Outstanding Faculty Advisor Award, 1989-1990 and 1991-92
 Procter and Gamble Best Paper Award of Merit, 2nd National Applied Mechanisms and Robotics Conference, November, 1991.
 George Wood Best Applied Mechanism Design Paper Award, 2nd National Applied Mechanisms and Robotics Conference, November, 1991.
 Wine Award for Excellence in Teaching, Virginia Polytechnic Institute and State University, 1992.
 Virginia Tech Academy of Teaching Excellence, Inducted 1992
 Procter and Gamble Best Paper Award of Merit, 22nd ASME Mechanisms Conference, Scottsdale, Arizona, September, 1992
 ASME National Faculty Advisor Award, 1995.
 Applied Mechanism Conference "Beyond the Call of Duty" Award for prodigious contributions to mechanism science, 1995.
 W. S. White Chair for Innovation in Engineering Education, Aug. 1996 to Aug. 1998
 Dean's Award for Excellence in Teaching, Virginia Tech College of Engineering, 1998
 South-Pointing Chariot Award, 1999 Applied Mechanisms and Robotics Conference, for lifetime contributions to the mechanisms community
 Ingersoll-Rand Faculty Award for Outstanding Contributions to the Mechanical Engineering Department, 2000
 National Instruments Award for Best Application of Measurement and Automation for the Development of a Tele-Operated CASE CX-160 Excavator Using FieldPoint, National Instruments Week 2002, Austin Texas, Aug 12-15, 2002.
 Virginia Tech Alumni Distinguished Professor, 2002-
 Outstanding Faculty Member Award, selected and awarded by the students in Mechanical Engineering, April, 2003.
 Fellow, American Society of Mechanical Engineers, 2003
 Alumni Teaching Award, Virginia Polytechnic Institute and State University, 2004
 National Instruments Virtual Instrumentation Applications Best Control Paper Award, Developing a Fully Autonomous Vehicle for Virginia Tech's Entry in the DARPA Grand Challenge," National Instruments NI Week 2006, Austin Texas.
 ASME Distinguished Service Award, 2005
 College of Engineering Certificate of Teaching Excellence, 2006-2007
 Volusia Manufacture's Association "Friend of Industry" Award, 2013

Funded Research

1. "Design Optimization of Spatial Mechanisms Subject to Real-World Constraints," National Science Foundation Grant MEA-8404313, June 15, 1984 through November 30, 1986, \$47,979, 100% Responsibility.
2. "Presidential Young Investigator Award: Interactive Spatial Mechanism Synthesis," National Science Foundation, Grant No. DMC 8657828, June 15, 1987 through January 31, 1993, \$312,000, 100% Responsibility.
3. "High-Speed Bearing Research," supported by the Industrial Drives Division of Inland Motor Corporation, Jan. 1, 1987 through Dec. 31, 1987, \$15,000, 100% Responsibility.
4. "Analysis of Warhead Structures," Department of the Navy, July 24, 1987 to November 15, 1987, \$99,348, Project Director with J. B. Kosmatka, R. H. Fries, A. L. Wicks, and L. D. Mitchell, Responsible for \$19,535.
5. "Analysis of Warhead Structures, Year 2," Department of the Navy, October 30, 1987 to March 31, 1988, \$174,000, Project Director with J. B. Kosmatka, R. H. Fries, A. L. Wicks, and L. D. Mitchell, Responsible for \$12,908.
6. "Hull Joint Model Test," Georgia Institute of Technology, May 16, 1988 to Aug. 16, 1988, \$10,141, Principal Investigator with R. H. Fries, Responsible for \$5,071.

7. "Design of Variable-Geometry Truss Manipulators," Virginia Center for Innovative Technology (CIT), 10/1/88 to 9/31/89, \$30,000, 100% Responsibility.
8. "Active Structures for Space Applications," 1/1/89 to 12/31/90, \$200,000, Principal Investigator with H. H. Robertshaw, Responsible for \$80,000.
9. "Computer-Aided Design of Fully-Wiped, Co-rotating Extruder Screws," Windward International and CIT, January 1, 1989 through December 31, 1989, \$44,029, Principal Investigator with Sanjay Dhande, Responsible for \$22,015.
10. "Construction of a NASP Mock-up," NASA Langley Research Center, February 1, 1989 to July 15, 1989, \$51,692, Principal Investigator with W. F. O'Brien, A. L. Wicks, and J. Marchman.
11. "Design of Advanced Manipulators for Steam Generator Maintenance," Babcock & Wilcox Co., November 1, 1989 to August 15, 1990, \$20,000, Principal Investigator with Sanjay Dhande, Responsible for \$15,000.
12. "Calibration, Control and Menu Design for an Advanced Steam-Generator Maintenance Manipulator," Babcock and Wilcox Co., February 1, 1991 through January 31, 1992, \$41,408, Principal Investigator with Sanjay Dhande, Responsible for \$31,056.
13. "Calibration, Control and Menu Design for an Advanced Steam-Generator Maintenance Manipulator," Virginia Center for Innovative Technology, February 1, 1991 through January 31, 1992, \$29,663, Principal Investigator with Sanjay Dhande, Responsible for \$22,247.
14. "Computer-Aided Design and Manufacture of Extruder Screw Elements," Windward International and CIT, July 1, 1990 through June 30, 1991, \$30,984, Principal Investigator with Sanjay Dhande, Responsible for \$15,492.
15. "Design of a Cellulose Acetate Preconditioning Heat Exchanger," Tennessee Eastman Co., October, 1990 through July, 1991, \$25,560, Principal Investigator with D. J. Nelson, Responsible for \$9,876.
16. "Continued Steam Generator Manipulator Support Based on Kinematic Control and Investigation of Vision Based Approach," Babcock and Wilcox Co., October 1, 1991 through September 31, 1992, \$40,000, Principal Investigator with A. L. Abbott, Responsible for \$32,000.
17. "Cellulose Acetate Packaging Study," Tennessee Eastman Co., October, 1991 through July, 1992, \$51,120, Principal Investigator with D. J. Nelson, Responsible for \$19,752.
18. "Continued Steam Generator Manipulator Support Based on Kinematic Control and Investigation of Vision Based Approach," Virginia CIT, January 1, 1992 through December 31, 1992, \$35,570, Principal Investigator with A. L. Abbott, Responsible for \$28,456.
19. "Preliminary Design of a Medical Waste Processing Machine," Virginia Center for Innovative Technology, June 1, 1992 through August 31, 1992, \$14,386, 100% Responsibility.
20. "Preliminary Design of a Medical Waste Processing Machine," Bioconversions Technologies, May 1, 1992 through January 31, 1993, \$16,377, 100% Responsibility.
21. "Conceptual Design of an Advanced Reactor Vessel Inspection Manipulator," B&W Nuclear Services Company, March 1, 1992 through February 28, 1993, \$30,000, 100% Responsibility.
22. "Engineering Development of a Medical Waste Processing Machine," Bioconversions Technologies, Aug. 15, 1992 to May 15, 1994, Principal Investigator with A. A. Kornhauser, \$93,088, responsible for \$46,544.
23. "Engineering Development of a Medical Waste Processing Machine," CIT, Aug. 15, 1992 to Aug. 14, 1993, Principal Investigator with A. A. Kornhauser, \$90,988, responsible for \$45,494.
24. "Enhancing the Capability and Performance of Nuclear Service Robots with Kinematic Analysis and Computer Vision," B&W Nuclear Services Co., Dec.1, 1992 to Nov. 30, 1993, with A. L. Abbott, \$50,000, responsible for \$40,000.

25. "Design of a Reactor Vessel Inspection Manipulator," B&W Nuclear Services, June 16, 1992 through June 15, 1993, \$100,146, 100% responsibility.
26. "Design of an Automated Needle/Armature Tray Loader," Siemens Automotive, Sept. 1, 1993 to Aug. 31, 1994, \$24,925, 100% Responsibility.
27. "Enhancing the Design and Performance of Nuclear Service Robots with Flexure Analysis, Computer Vision, and Optimization Techniques," B&W Nuclear Technologies, Dec.1, 1993 to Nov. 30, 1994, with A. L. Abbott, \$40,000, responsible for \$30,000.
28. "Enhancing the Design and Performance of Nuclear Service Robots with Flexure Analysis, Computer Vision, and Optimization Techniques," Center for Innovative Technology, Feb. 1, 1994 to Jan. 31, 1995, with A. L. Abbott, \$47,023, responsible for \$35,000.
29. "Design Studies for Nautilus," Nautilus, Inc, Jan.1, 1994 to Oct. 15, 1994, \$7,723, 100% responsibility.
30. "Design Studies for Nautilus," Center for Innovative Technology, Jan.1, 1994 to Dec. 31, 1994, \$13,795, 100% Responsibility.
31. "Rod Formation Dynamics," R. J. Reynolds Co., Jan. 1, 1994 to Dec. 31, 1994, with D. J. Nelson, 116,557, 50% Responsibility.
32. "A Short-term Proposal to Develop Cam-Design Software for Cadkey, Inc.," June 16, 1994 to Sept 15, 1994, \$9,981, 100% Responsibility.
33. "Design of an Automated Injector Body Tray Loader," Siemens Automotive, Sept. 1, 1994 to Aug. 31, 1995, \$20,744, 100% Responsibility.
34. "Design Studies for Nautilus," Nautilus, Inc, Dec 1, 1994 to Nov. 30, 1995, \$23,731, 100% Responsibility.
35. "Design Studies for Nautilus," Center for Innovative Technology, Dec.1, 1994 to Dec. 31, 1995, \$25,924, 100% Responsibility.
36. "Preliminary design and Equipment Selection for a Mulch-Making Machine," Fred Whitaker Co., June 1, 1995 to Dec. 31, 1995, \$10,920, %100 Responsibility.
37. "Improving the Kinematic Control of Robots with Computer Vision," NSF, July 15, 1995 to June 30, 1996, \$22,026, %100 Responsibility.
38. "Proposal to Increase Funding in Siemens Valve-Body Loader Project," Siemens Automotive, \$7,018, 100% Responsibility.
39. "Preliminary Design and Equipment Selection for a Mulch-Making Machine," CIT, June 1, 1995 to August 31, 1995, \$8,185, %100 Responsibility.
40. "Design of a Personal Smith Machine," Nautilus, Inc, July 1, 1995 to Oct. 31, 1995, \$12,273, 100% Responsibility.
41. "Development of Advanced Control Strategies for Variable Geometry Truss Manipulators," Batelle-Pacific Northwest Laboratory, Jan. 1, 1995 to June 31, 1995, \$10,000, with R. J. Salerno, 10% Responsibility.
42. "Curriculum Renewal in Mechanical Engineering at Virginia Tech," NSF SUCCEED, Sept. 15, 1995 to Dec. 15, 1995, with Paul Tidwell, \$4,500 (NSF), \$4,677 (Cost Sharing), 50% Responsibility.
43. "Development of a Parallel Architecture Robotic Wrist," Triad Investors, Jan. 1, 1996 to May 31, 1997, \$51,707, 100% Responsibility.
44. "Development of Advanced Control Algorithms for Variable Geometry Truss Manipulators," Batelle-Pacific Northwest Laboratory, Jan. 1, 1996 to June 31, 1996, \$10,000, 100% Responsibility.

45. "Curriculum Renewal in Mechanical Engineering at Virginia Tech – Year 5," NSF SUCCEED, June 16, 1996 to June 15, 1997, \$10,000 (NSF), \$10,000 (Cost Sharing), 100% Responsibility.
46. "Technology Assessment for a Robotic Vacuum Cleaner," Servus Robots Incorporated, Sept.1, 1998 to Feb. 28, 1999 with John Bay, Bob Sturges, and Mike Deisenroth, \$8,333, 25% Responsibility.
47. "Technology Assessment for a Robotic Vacuum Cleaner," Virginia CIT, Oct.1, 1998 to March 31, 1999 with John Bay, Bob Sturges, and Mike Deisenroth, \$25,000, 25% Responsibility.
48. "MBC Guidance Project," Long-Airdox Company, August 1998 to July 1999, P.I.: R.H. Sturges, Co-P.I.'s: M. P. Deisenroth, C.F. Reinholtz. \$100,000.
49. "MBC Guidance Project," Virginia Center for Innovative Technology (matching), August 1998 to July 1999, P.I.: R.H. Sturges, Co-P.I.'s: M. P. Deisenroth, C.F. Reinholtz. \$100,000.
50. "Vertical Integration of Mechatronics at Virginia Tech," NSF SUCCEED, Aug 1999 to July 2002, P.I.: W. R. Saunders, Co-P.I.'s: J. S. Bay, D. J. Leo, C.F. Reinholtz, \$18,000/year for three years.
51. Development of a Remote Controlled CASE CX-160 Excavator, Naval Surface Warfare Center, Dahlgren G-64 Division, February, 2003 to September, 2003, Co-PI with A. L. Wicks, \$17,000
52. Investigation of Adaptive Structures for Morphing Aircraft, NASA Langley Research Center, \$65,078, July 1,2002 to June 30, 2003, 25% (with H. Robertshaw and D. Inman).
53. Increased Scope for Delivery Orders 0019, Remote Control Excavator, Naval Surface Warfare Center, with Al Wicks, PI, \$21,223.
54. Develop the Joint Unmanned Systems Experimentation and Research (JOUSTER) Site, U.S Army RDECOM STTC, Orlando, FL, June 10, 2004 to June 9, 2007, \$12,200,000, C. Reinholtz, PI (55% Responsibility), A. Wicks, Co-PI (43% Responsibility), Carstensen Co-PI (2% Responsibility).
55. Virginia First Lego League 2004 Pilot High School Robotics Program, NASA Langley Research Center, Education Grant NNL04AA65G, \$20,000, July 9, 2004 to July 8, 2005, 100% Responsibility
56. Virginia First Lego League NIA Outreach Program, National Institute of Aerospace, Grant No. VT-03-1, \$8,000, February 1, 2005 to August 31, 2005, 100% Responsibility.
57. Heterogeneous Teams Of Autonomous Vehicles: Advanced Sensing And Control, Office of Naval Research, Dennis W. Hong, Naira V. Hovakimyan, Marty E. Johnson, Charles F. Reinholtz, Daniel J. Stilwell, A. L. Wicks, Craig A. Woolsey, Christopher L. Wyatt, 07/01/05 – 6/30/06, Total Funding: \$1,050,000, C. F. Reinholtz share: \$52,752.
58. Coordinated Sensing and Control for Surveillance and Tracking by Heterogeneous Autonomous Vehicle Teams, Daniel J. Stilwell, Christopher L. Wyatt, Craig A. Woolsey, Naira V. Hovakimyan, A. L. Wicks, Andy Kurdila, Charles Reinholtz and Michael Roan, 5/15/06 – 9/14/07, \$1,417,500, Reinholtz share: \$184,275.
59. Development Of An Autonomous Vehicle For The DARPA Urban Challenge, with Al Wicks and Dennis Hong, the Defense Advanced Research Projects Agency, 10/1/06 to 12/31/07, \$999,274.
60. Development of a Drive-by-Wire Commercial Vehicle, General Dynamics Robotics Systems (GDRS), \$54,256, 1-11-07 to 6-30-07.
61. Navigation And Autonomous Control For Nemesis, Applied Research Associates, Inc. (ARA), \$61,513, 7-1-06 to 6-30-07

62. Dynamic Model of CAT 777-797 Haul Trucks for Autonomous Operation, Caterpillar, \$74,303, 7-1-06 to 6-30-07
63. Boeing Digitally Manufactured UAV Project, \$22,740, , The Boeing Company, 10-15-2010 to 12-31-2010.
64. Reconnaissance and Autonomy for Small Robots – Canine (RASR-K9), Robotic Research, \$17,951.50, 1-1-2011 to 4-30-2012
65. Proposal to Develop an Autonomous Maritime System to Compete in the International Maritime Robotics Competition, AUVSI and the Office of Naval Research, \$30,000, 10-1-13 to 12-31-14.

Refereed Papers in Major Technical Journals

1. Christine M. Dailey, Charles Reinholtz, Thais Russomano, Michael Schuette, Rafael Baptista, Rodrigo Cambraia, “Resistance Exercise Machine within Lower Body Negative Pressure for Counteracting Effects of Microgravity”, *Gravitational and Space Research*, Vol 2, No. 1 ISSN: 0898-4697, 2014.
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66. Shooter, S. B. and Reinholtz, C. F., "Extrinsic Calibration of Portable Manipulators," Proceedings of the 22nd ASME Mechanisms Conference, DE-VOL 45, September 1992, pp. 501-506.
67. Shooter, S. B., Reinholtz, C. F. and Dhande, S. G., "On the Kinematic Design of Manipulators For Limited Access Workspaces (LAWS)," Proceedings of the 22nd ASME Mechanisms Conference, DE-VOL 45, September 1992, pp. 485-491.
68. Tidwell, P. H., Bandukwala, N., Dhande, S. G., Reinholtz, C. F. and Webb, G., "Synthesis of Wrapping Cams," Proceedings of the 22nd ASME Mechanisms Conference, DE-VOL 46, September 1992, pp. 337-343.
69. Padmanabhan, B., Tidwell, Salerno, R. J. and Reinholtz, C. F., "VGT-Based Gimbals: Practical Construction and General Theory," Proceedings of the 22nd ASME Mechanisms Conference, DE-VOL 47, September 1992, pp. 437-443.
70. Arun, V., Padmanabhan, B., Kolady, K., and Reinholtz, C. F., "Determination of the workspace of the 3-DOF Double-Octahedral Variable-Geometry Truss Manipulator," Proceedings of the 22nd ASME Mechanisms Conference, DE-VOL 45, September 1992, pp. 493-500.
71. Tidwell, P. H., Glass, S. W., Hildebrand, J. J., Reinholtz, C. F., and Shooter, S. B., "COBRA - Design and Development of a Manipulator for Nuclear Steam Generator Maintenance," Proceedings of the 2nd National Applied Mechanisms and Robotics Conference, November 3-6, 1991, Cincinnati, Ohio, (Winner of Proctor and Gamble Best Paper Award and Winner of The George Wood Best Applied Paper Award).
72. Stulce, J. R., and Reinholtz, C. F., "Observations on Caterpillar Locomotion and Their Application to a Crawling Robot," Proceedings of the 2nd National Applied Mechanisms and Robotics Conference, November 3-6, 1991, Cincinnati, Ohio.
73. Stulce, J. R., W. D. Burgos, S. G. Dhande, and C. F. Reinholtz, "Conceptual Design of a Multibody Passive-Legged Crawling Vehicle," Proceedings of the 1990 ASME Mechanisms Conference, DE-Vol. 26, Cams, Gears Robot and Mechanism Design, Sept. 16-19, 1990, pp. 199-205.
74. Arun, V., and C. F. Reinholtz, L. T. Watson, "Enumeration and Analysis of Variable Geometry Truss Manipulators," Proceedings of the 1990 ASME Mechanisms Conference, DE-Vol. 26, Cams, Gears Robot and Mechanism Design, Chicago, IL, Sept. 16-19, 1990, pp. 93-98.
75. Dhande, S. G., B. Padmanabhan, C. F. Reinholtz, and R. S. Voruganti, "Computer-Aided Design and Manufacture of Approximate Ruled Surfaces," Proceedings of the Second International Conference on Computer Integrated Manufacturing, IEEE Computer Society Press, Troy, NY, May 21-23, 1990, pp. 137-142.
76. Tidwell, P. H., C. F. Reinholtz, H. H. Robertshaw, C. G. Horner, "Kinematic Analysis of Generalized Adaptive Trusses," First Joint US/Japan Conference on Adaptive Structures, Maui, Hawaii, November 13-15, 1990.
77. Padmanabhan, B., and C. F. Reinholtz, "Design of Robotic Manipulators Using Variable-Geometry Trusses as Joints," paper 89 AMR-8C-7, Proceedings of the First National Applied Mechanisms and Robotics Conference, Vol. II, 1989.
78. Thompson, J. M., C. F. Reinholtz, and A. Myklebust, "Exact Analysis and Synthesis of the RSCR Spatial Mechanism," ASME paper No. 88131, Trends and Developments in Mechanisms, Machines and Robotics--1988 Proceedings of the 20th Mechanisms Conference, Orlando, FL, Sept. 25-28, 1988.
79. Williams, R. L., II, C. F. Reinholtz, "Forward Dynamic Analysis and Power Requirement Comparison of Parallel Robotic Mechanisms," ASME paper No. 88078, Trends and Developments in Mechanisms, Machines and Robotics--1988 Proceedings of the 20th

Mechanisms Conference, Orlando, FL, Sept. 25-28, 1988. (Also accepted for publication in the ASME Journal of Mechanisms, Transmissions and Automation in Design, 1989.)

80. Williams, R. L., II, C. F. Reinholtz, "Closed-Form Workspace Determination and Optimization for Parallel Robotic Mechanisms," ASME paper No. 88079, Trends and Developments in Mechanisms, Machines and Robotics--1988 Proceedings of the 20th Mechanisms Conference, Orlando, FL, Sept. 25-28, 1988.
81. Robertshaw, H. H., and C. F. Reinholtz, "Variable Geometry Trusses," Proceedings of the US Army Research Office Workshop on Smart Materials, Structures and Mathematical Issues, Sept. 15-16, 1988.
82. Salerno, R. J., C. F. Reinholtz, and H. H. Robertshaw, "Shape Control of High Degree of Freedom Variable Geometry Trusses," presented at the NASA Workshop on Controls/Structures Integration, Williamsburg, VA, July 11-13, 1988.
83. Williams, R. L., II, C. F. Reinholtz, "Closed-Loop Planar Manipulators: Part I - Forward and Inverse Kinematics; Part 2 - Workspace Optimization," Proceedings of the 10th Applied Mechanisms Conference, Dec. 6-9, 1987, New Orleans, Louisiana.
84. Rogers, C. A., H. H. Mabie, and C. F. Reinholtz, "Numerical Determination of Accuracy Points Using Chebyshev Polynomials for Displacement and Velocity Synthesis," Proceedings of the 10th Applied Mechanisms Conference, Dec. 6-9, 1987, New Orleans, Louisiana.
85. Mabie, H. H., C. F. Reinholtz, and C. A. Rogers, "Determination of Hob Offsets to Maximize the Ratio of Recess to Approach Action and Balance Tooth Strengths for Nonstandard Spur Gears by Limit Analysis," Proceedings of the 10th Applied Mechanisms Conference, Dec. 6-9, 1987, New Orleans, Louisiana.
86. Mabie, H. H., C. F. Reinholtz, and C. A. Rogers, "Determination of Pinion Cutter Offsets to Maximize Recess to Approach Action or to Equalize Tooth Strengths of Nonstandard Spur Gears with Backlash," Proceedings of the 10th Applied Mechanisms Conference, Dec. 6-9, 1987, New Orleans, Louisiana.
87. Reinholtz, C. F., and D. Gokhale, "Design and Analysis of Variable Geometry Truss Robots," Proceedings of the 10th Applied Mechanisms Conference, Dec. 6-9, 1987, New Orleans, Louisiana.
88. Reinholtz, C. F., V. Arun, and R. L. Williams, A Reassessment of the Tasks of Kinematic Synthesis," Proceedings of the 10th Applied Mechanisms Conference, Dec. 6-9, 1987, New Orleans, Louisiana.
89. Arun, V., and C. F. Reinholtz, "Design of the RCCC Spatial Mechanism," Proceedings of the 10th Applied Mechanisms Conference, Dec. 6-9, 1987, New Orleans, Louisiana.
90. Klatt, M. A., and C. F. Reinholtz, "Mechanism Optimization Using Zero-Order Methods and Penalty Functions: A Comparison of Incremented Versus Nonincremented Penalty Parameter," DE-VOL. 10-1, Advances in Design Automation, Vol. 1, Proceedings of the 1987 Design Automation Conference, Boston, MA, Sept. 27-30, 1987, pp. 205-213.
91. Rogers, C. A., R. E. Cobb, and C. F. Reinholtz, "Incorporating Computer Programming Projects Into the Mechanical Engineering Curriculum," Proceedings of the Fifth National Conference on University Programs in Computer-Aided Engineering, Design, and Manufacturing (UPCAEDM '87), pp. 176-180.
92. Williams, II, R. L., C. F. Reinholtz, and A. Myklebust, "Complete Function-Generation Synthesis and Design of RSSR Spatial Mechanisms," ASME Paper 86-DET-151, presented at the 19th ASME Mechanisms Conference, Columbus, Ohio, October, 1986.

93. Reinholtz, C. F., "Integrating Computers into Kinematics Courses at VPI&SU," Proceedings of the Fourth National Conference on University Programs in Computer-Aided Engineering, Design and Manufacture, August, 1986, pp. 127-130.
94. Mabie, H. H., C. F. Reinholtz, D. Puzio, and G. M. Irwin, "Optimum Design of Spur Gear Teeth Cut with a Hob," Proceedings of the Ninth Applied Mechanisms Conference, Kansas City, MO, 1985, Vol. 2, Session VIII.B, Paper VI.
95. Keil, M. J., A. Myklebust, and C. F. Reinholtz, "Prediction of Link Interference in Planar Mechanisms," Proceedings of the Ninth Applied Mechanisms Conference, Kansas City, MO, 1985, Vol. 1, Session III.B, Paper V, (Winner of Proctor and Gamble Best Paper Award).
96. Myklebust, A., C. F. Reinholtz, W. H. Francis, and M. J. Keil, "Design of a Radar Guidance Mechanism Using MECSYN-ANIMEC," ASME Paper 84-DET-139, presented at the 18th ASME Mechanisms Conference, Cambridge, Massachusetts, October 10, 1984.
97. Sandor, G. N., A. G. Erdman, E. Raghavacharyulu, and C. F. Reinholtz, "On the Equivalence of Higher and Lower Pair Planar Mechanisms," Proceedings of the Sixth World Congress of the International Federation for the Theory of Machines and Mechanisms, New Delhi, India, 1983.
98. Sandor, G. N., D. Kohli, X. Zhuang, and C. F. Reinholtz, "Synthesis of a Five-Link Spatial Motion Generator," ASME paper 82-DET-130, 1982.
99. Sandor, G. N., D. Kohli, A. Ghosal, and C. F. Reinholtz, "Closed-Form Analytic Synthesis of a Five-Link Spatial Motion Generator," Proceedings of the Seventh Applied Mechanisms Conference, Kansas City, MO, 1981, pp. XXVI-1 to XXVI-7

Patents

1. "Spatial, Parallel-Architecture, Robotic Carpal Wrist," U. S. Patent 5,699,695, Inventors: Canfield, S. L., Reinholtz, C. F., Salerno, R. J., and Ganino, Anthony J., Assignee: Virginia Tech Intellectual Properties, Inc., Awarded December 23, 1997.
2. "Snubber Profile," U. S. Patent 4,998,942, Inventor: Reinholtz, Charles F. Assignee: Milliken Research Corporation, Spartanburg, S.C., Awarded March 12, 1991.

Invited Presentations at National Meetings

1. "Test Drive an Autonomous Vehicle: Experiences from the 2007 DARPA Urban Challenge," Presentation to USAA, 19 January 2009, San Antonio, TX
2. "Challenges and Opportunities Offered by the DARPA Grand Challenge," Invited Presentation and Panel Discussion at the 2004 AIAA Unmanned Aerial Vehicle Conference, Chicago, IL, September, 2004.
3. "Product Safety and Product Liability," Invited Lecture at the 2001 ASME World Congress, New York, NY, Nov.13, 2001
4. "Life after Tenure" Invited Speaker and Panelist at the ASEE Annual Conference and Exposition, Charlotte NC, June 20-23, 1999.
5. "Reduced Complexity Robotics," Invited presentation at the 1998 ASME Design Technical Conferences, 25th Biennial Mechanisms Conference, Atlanta, GA, September 1998.
6. "Trends and Opportunities in Mechanisms Research," Plenary Panel Session Speaker at the 4th National Applied Mechanisms and Robotics Conference, Cincinnati, Ohio, December 10-14, 1995.
7. "Trends and Opportunities in Robotics," Opening Plenary Session Lecture at the 10th Applied Mechanisms Conference, Dec. 6-9, 1987, New Orleans, Louisiana.

8. "Observations on Robotics and Mechanisms Research," Opening Plenary Panel Session Speaker at the 2nd National Applied Mechanisms and Robotics Conference, November 3-6, 1991, Cincinnati, Ohio, November 3-6, 1991.

University Service

Invited Speaker at the following University Events and Alumni Association Chapter Meetings:

June 23, 2005, Research Triangle Park Alumni Chapter, Raleigh, NC

March 18, 2004, Greensboro, NC Triad Alumni Chapter

March 31, 2004, Atlanta Alumni Chapter

November 1, 2004, Committee of 100 - Hotel Roanoke

November 21, 2004, Class of 1968, Donaldson Brown

Fulbright Scholarship Advisory Committee 2005

Advisor to the Virginia Tech Autonomous Aerial Vehicle Competition Team, 2004-

Advisor to the Virginia Tech DARPA Grand Challenge Team, 2003-

Virginia FIRST Lego League Coordinator, 2002-

Advisor to the Virginia Tech Intelligent Ground Vehicle Competition Team, 1995-

Advisor to Entering Honors Students 2003-

Horton Honors Scholarship Selection Committee 2003-

Member, University Strategic Planning Committee, 2001

Chair, Virginia Tech Academy of Teaching Excellence 2000-2001

Vice Chair, Virginia Tech Academy of Teaching Excellence 1999-2000

Member, University Promotion and Tenure Committee 2000-2001

Member, College Promotion and Tenure Committee 2000-2001

Chair, Mechanical Engineering Curriculum Committee 1997-2002

Chair, Mechanical Engineering ABET Review, 1998-2002

Member, College of Engineering Curriculum Committee 1997-2002

Member, 1st Year Special Curriculum Review Committee 1997

Member, Engineering Dean Search Committee, 1993-4

Chairman, Mechanical Engineering Honors and Awards and Publicity Committee, 1993-99

Member, Mechanical Engineering Honors and Awards and Publicity Committee, 1993-99

Chairman, College Wine Teaching Award Committee, 1992-95

Chairman, University Wine Teaching Award Committee, 1995-96

Member, Mechanical Engineering Department Head Search Committee, 1992-93

Member, Mechanical Engineering Curriculum Committee, 1984-87, 1992-2004

Member, Mechanical Engineering Tenure and Promotion Committee, 1989-2004

Member, Mechanical Engineering Graduate Committee, 1987-89

Member, Mechanical Engineering Recruiting Committee, 1992-93

Member, Sigma Xi High School Teaching Award Committee 1987-88, Chairman 1989

Member, College of Engineering Commencement Committee, 1988-

Faculty Advisor to the Virginia Tech Student Section of ANS, 1993-

Faculty Advisor to the Virginia Tech Student Section of ASME, 1988-

Faculty Advisor to the Virginia Tech Chapter of Tau Beta Pi, 1984-88

Host for the Virginia Tech Academic Challenge, 1991

Professional Service

Society

ASME

Positions Held

Secretary of the Virginia Section 1987-92

Chairman of the National Student Mechanism Competition 1987-88

Chairman of the Joint Regional Conference 1989 and 2000

Virginia Tech Student Section Advisor, 1988-2007

Member of the ASME Mechanisms Committee, 1990-1993

Associate Technical Editor, *ASME Journal of Mechanical Design*, 1991-93

Paper Review Chairman, 22nd ASME Mechanisms Conference, Sept. 1992
 Conference Arrangements Chairman, 23rd ASME Mechanisms Conference, Sept. 1994
 Member, ASME National Design Contest Committee, 1996-2002
 Virginia Section Newsletter Editor, 1994-2000
 Region IV Senior Representative to the National Student Sections Committee, 1995-2000

Sigma Xi High School Teaching Award Committee, Member 1987-88, Chair 1989

ANS Student Section Advisor, Virginia Tech, 1993-95

NAE Invited review Board member, National Academies' National Research Council (NRC)
 Army Research Laboratory Technical Assessment Board (ARLTAB), May, 2004

Graduate Advising

Master's Degree Students Completed				
	Degree	Name	Completion Date	Title
1	MS	Robert L Williams, II	8/85	Synthesis and Design of the RSSR Spatial Mechanism for Function Generation
2	MS	Arun Veeraraghavan	3/86	Computer Aided Design of the RCCC Spatial Mechanism
3	MS	Michael A. Klatt	10/86	Design Optimization of Planar Mechanisms
4	MS	Kevin K. Moyers	11/87	A Microcomputer-Based Data Acquisition System for Diagnostic Monitoring of High-Speed Electric Motors
5	MS	Christodoulos S. Demetriou	12/87	A PC Implemented Kinematic Synthesis System for Planar Mechanisms
6	MS	Dipen P. Gokhale	12/87	Kinematic Analysis and Animation of a Variable-Geometry Truss Robot
7	MS	William R. Seith	5/88	Design of a Flying Cutter
8	MS	George M. Clessas	5/88	Direct Calculation of Cable Tension in a Store Separation Program Which Models the Launch of an Aerial Tow Target
9	MS	Mark W. Biegler	8/88	Determination of Stress Concentration Factors Using Experimental Methods
10	MS	Nandan Joshi	2/88	Mobility Analysis of Variable-Geometry Trusses
11	MS	Vasant Marathe	12/88	Design of a Hot Melt Book Binding Machine
12	MS	Babu Padmanabhan	12/88	Design of a Robotic Manipulator Using Variable-Geometry Trusses as Joints
13	MS	Robert J. Salerno	6/89	Shape Control of High Degree-of-Freedom Variable-Geometry Truss Manipulators
14	MS	Ravinder S. Voruganti	8/90	Symbolic and Computational Conjugate Geometry for Design and Manufacturing Applications
15	MS	Steven B. Shooter	12/90	Conceptual Manipulator Design for Limited Access Workspaces
16	MS	Paul Mele	5/91	Mechanical Design of a Stewart Platform-Based Crawling Vehicle
17	M.S.	William K. Carpenter	12/92	Design of Medical Waste Treatment Systems Employing Bioremediation

18	MS	Allen Maples	5/93	Design of a Robust Acoustic Positioning System for an Underwater Nuclear Reactor Vessel Inspection Robot
19	MS	William Cordle	5/93	Numerical Inverse Kinematics for a Six Degree-of-Freedom Manipulator
20	MS	Glenn Melnyk	6/93	Mechanisms for Automated Toolhead Changing in Nuclear Steam Generator Robotics
21	MS	Steve Payne	5/94	A CAD-Interactive Software Package for the Synthesis of Planar Disk Cams
22	MS	Anil K. Garg	8/94	Design, Installation and Testing of a Bioremediation-Based System for Treating Regulated Medical Waste
23	MS	Todd Denkins	12/94	Design Methodology to reduce the Number of Actuators in Complex Mechanisms
24	MS	Joseph Calkins	12/94	Real-Time Compensation of Static Deflections in Robotic Manipulators
25	MS	Randy Soper	8/95	Synthesis of Planar Four-Link Mechanisms for Force Generation
26	MS	Keith Garguilo	8/95	Design and Testing of a Nonlinear Mechanical Advantage Demonstration Mechanism
27	MS	Ganino, A. J.	5/96	Mechanical Design of the Carpal Wrist: A Parallel-Actuated, Singularity-Free Robotic Wrist
28	MS	Larkin, Susan	6/96	Wheeled Autonomous Mobile Robots for use in Harsh Environments: A Survey of Recent Publications
29	MS	Iskandar, Kurnia	6/96	Computer Assisted Synthesis of Wrapping Cam Mechanisms
30	MS	Riutort, Kevin	7/96	Applied Design and Implementation of Straight-Line Mechanisms
31	MS	Saccoccio, Greg	8/96	Error Modeling of the Carpal Wrist
32	MS	Scardina, Mike	10/96	Optimal Synthesis of Force-Generating Planar Four-Link Mechanisms
33	MS	Palmer, Matthew	12/96	Kinematics of Beam-Flexure Four-Bar Linkages With Applications in a Compound Bow
34	MS	Coombs, Dana	2/97	Design of User-Weight-Based Exercise Machines
35	MS	Doyle, Matthew	12/97	The Foundation for CADSPAM
36	MS	Hayes, Thomas J.	12/97	The Creative Entrepreneurs Organization
37	MS	Adler, Alex	5/98	Testing and Understanding Screwdriver Bit Wear
38	MS	Haynie, C. Dean	8/98	Mechanical Design and Navigation Strategies for a Zero-Turn-Radius Autonomous Vehicle
39	MS	Holland, Michael	12/98	Assembly Optimization for Double-Row Ball Bearings
40	MS	Abbott, Michael	6/00	Dynamics and Control of the Biplanar Bicycle
41	MS	Conner, David	8/00	Sensor Fusion, Navigation, and Control of Autonomous Vehicles
42	MS	Jillcha Wakjira	1/01	Design of a SMA Heat Engine
43	MS	Carr, Angela	5/01	Position Control Comparison of Equilibrated and Mass Counterweight Systems

44	MS	Kedrowski, Philip	5/01	Development and Implementation of a Self-Building Global Map for Autonomous Navigation
45	MS	Blackett, Ricardo	5/01	Optimization of Multi-Degree-of-Freedom Force Generating Mechanisms
46	MS	Matthew Thompson	7/01	Design of a Cyclic Sliding, Dynamically Loaded Wear Testing Device for the Evaluation of Total Knee Replacement Materials
47	MS	Rundgren, Brian	12/01	Design and Optimization of Force Generation Linkages to Include Dynamic Effects
48	MS	Schiller, Ean	9/02	Heat Engine Driven by Shape Memory Alloys: Prototyping and Design
49	MS	Gopinath, Sudir	12/02	Using Color and Shape Analysis for Boundary Line Extraction in Autonomous Vehicle Applications
50	MS	Whittier, Will	12/02	Kinematic Analysis of Tensegrity Structures
51	MS	Terwelp, Chris	5/03	Remote Control of Hydraulic Equipment for Unexploded Ordnance Remediation
52	MS	Henshaw, Graham	5/03	Single-Session Design: Design Methodology in Compressed Timeframes Derived from the Robot Rivals Television Series
53	MS	Corey, Chris	12/03	Epicyclic Gear Train Solution Techniques with Application to Tandem Bicycling
54	MS	Fleming, Michael	12/03	Teleoperated Control of Hydraulic Equipment for Hazardous Material Handling
55	MS	Stubbs, Matthew	12/03	Kinematic Design and Analysis of a Morphing Wing
56	MS	Bacha, Andrew	5/05	Line Detection and Lane Following for an Autonomous Robot
57	MS	Frentzel, John	5/05	A Wireless Instrumented Payload for Testing Unmanned Vehicles
58	MS	Naik, Ankur	12/05	Arc Path Collision Avoidance Algorithm for Autonomous Ground Vehicles
59	MS	Barnett, Shane	12/05	Development of a Tow Capacity Test Device for Small Unmanned Vehicles
60	MS	Cooper, Jared	12/05	Modeling of a Small-Scale Remote Controllable Helicopter for Simulation and Control Development
61	MS	Baity, Sean	5/06	Development of a Next-generation Experimental Robotic Vehicle (NERV) that Supports Intelligent and Autonomous Systems Research
62	MS	Leedy, Brett	5/06	Two Minds for One Vehicle: A Case Study in Deliberative and Reactive Navigation
63	MS	Gombar, Brett	5/06	Design and Evaluation of a Mobile Instrumentation Platform for Unmanned Vehicle Testing
64	MS	Putney, Joseph	5/06	Reactive Navigation of an Autonomous Ground Vehicle Using Dynamic Expanding Zones
65	MS	Willis, Christopher Ryan	5/06	A Kinematic Analysis and Design of a Continuously Variable Transmission

66	MS	James Hayward Bittorf	6/06	Mechanical Device to Assist the Landing of Unmanned Aerial Vehicles
67	MS	Ramirez, Rachael	8/06	Computer Vision Based Analysis of Broccoli for Application in a Selective Autonomous Harvester
68	MS	Grant Edward Gothing	7/07	Development of the “Discretized Dynamic Expanding Zones with Memory” Autonomous Mobility Algorithm for the Nemesis Tracked Vehicle Platform
69	MS	Thomas James Alberi	4/08	A Proposed Standardized Testing Procedure for Autonomous Ground Vehicles
70	MS	Patrick Norman Currier	4/08	Development of an Automotive Ground Vehicle Platform for Autonomous Urban Operations
71	MS	Jesse Lee Farmer	2/08	Kinematic Analysis Of A Two Body Articulated Robotic Vehicle
72	MS	Chris Hockley	12/10	Development of an Autonomous Monocopter
73	MS	Katrina Corley	4/11	Supervisory Autonomous Control of Homogeneous Teams of Unmanned Ground Vehicles, With Application to The Multi-Autonomous Ground-Robotic International Challenge
74	MS	Robert Andrew Lister	5/11	Classification of Marine Vessels in a Littoral Environment Using a Novel Training Database
75	MS	Kevin Rigby	8/11	Localization of Aircraft Using Wide-Baseline Stereopsis
76	MS	Lafe Zabowski	8/11	A Low Cost, Computer Vision Based, Target Tracking Hexapod
77	MS	Christine Dailey	5/12	A Novel Resistance Exercise Machine for Use in a Lower Body Negative Pressure Box to Counteract the Effects of Weightlessness

Ph.D. Students Completed				
1	PhD	Robert L. Williams II	5/88	Planar Robotic Mechanisms: Analysis and Configuration Comparison
2	PhD	Arun Veeraraghavan	9/90	The Solution of Variable-Geometry Truss Problems Using New Homotopy Continuation Methods
3	PhD	Shahriar Tavakkoli	6/91	Shape Design Using Intrinsic Geometry
4	PhD	Babu Padmanabhan	12/92	A Study of Isostatic Framework With Application to Manipulator Design
5	PhD	Robert J. Salerno	12/93	Positional Control Strategies for a Modular, Long-Reach, Truss-Type Manipulator
6	PhD	Paul Tidwell	8/95	Wrapping Cam Mechanisms
7	PhD	J. Barry Fallon	8/95	Improving the Kinematic Control of Robots by Estimating the End-Effector Pose Directly with Computer Vision
8	PhD	Steven B. Shooter	12/95	Information Modeling in Mechanical Design: With Application to Cam Mechanism Design
9	PhD	Ravi S. Voruganti	12/95	Robot System Characterization: Error Modeling, Identification, Analysis and Calibration
10	PhD	Canfield, Steve	5/98	Development of the Carpal Wrist

11	PhD	Stulce, John	1/02	Conceptual Design of a Multibody Passive-Legged Crawling Vehicle
12	PhD	Calkins, Joseph	8/02	Quantifying Coordinate Uncertainty Fields In Coupled Spatial Measurement Systems
13	PhD	Snorri Gudmundsson	12/16	A Biomimetic, Energy-Harvesting, Obstacle-Avoiding, Path-Planning Algorithm for UAVs

December 7, 2018 TLR

Consulting Experience and Prior Testimony, 1987-2016

Expert Witness Consulting Experience (Organization retaining my services shown in boldface):

1. 1987-91, **Gilmer, Sadler, Ingram, Sutherland and Hutton**, Pulaski, VA. Product liability work involving a loading dock accident
2. 1991-93, **Campbell, Greg**, Blacksburg, VA. Product liability investigation involving a reclining chair accident
3. 1992-95, **Gilmer, Sadler, Ingram, Sutherland and Hutton**, Pulaski, VA. Product liability investigation involving a truck accident
4. 1993, **Bird, Kinder and Huffman**, Product liability investigation involving a truck steering mechanism failure
5. 1993, **Gilmer, Sadler, Ingram, Sutherland and Hutton**, Pulaski, VA., Product liability investigation involving a chair-lift mechanism
6. 1993-95, **Lowe, Price, LeBlanc and Becker**, Patent infringement case involving a cam mechanism
7. 1994, **Woods, Rodgers and Hazlegrove**, Product liability case involving rail transport mechanism investigation
8. 1995-97, **Gilmer, Sadler, Ingram, Sutherland and Hutton**, Pulaski, VA., Marshall L. Ritter, Jr. v. Numa Tool Company., Inc., et al, Product liability investigation involving a cable failure
9. 1996-97, **Gilmer, Sadler, Ingram, Sutherland and Hutton**, Pulaski, VA., Product liability investigation involving a cafeteria chair failure
10. 2000, **Foley and Lardner**, Chicago IL, Patent infringement case involving a plastic bag zipper mechanism
11. 2002, **DeCaro, Doran, Siciliano, Gallagher & DeBlasis**, Civil Action 01-1508, Fish v. Fitness Quest, Inc., et al Product liability investigation involving an exercise machine
12. 2004, **Gilmer, Sadler, Ingram, Sutherland and Hutton**, Pulaski, VA, Hicks v. Werner Ladder Co., Product liability investigation involving a ladder failure
13. 2005, **Gilmer, Sadler, Ingram, Sutherland and Hutton**, Pulaski, VA, Garry Stoots v. Werner Co., et al., Product liability investigation involving a ladder failure

14. 2005-08, **Fish & Richardson**, Washington, DC, The Saunders Group, Inc. v. Comfortrac, Inc. and Care Rehab and Orthopaedic Products, Inc., Patent infringement involving a cervical traction device
15. 2006, **Clark and Brody, Washington, DC**, American Seating Company v. USSC Group, Inc., Civil Action No. 1:01-CV-578, Patent Infringement Case involving a wheelchair restraining mechanism
16. 2006-07, **Hogan and Hartson**, Patent infringement investigation involving a brick-making machine
17. 2006-07, Banner and Witcoff, Chicago, IL, **Lexmark** v. Static Controls Corporation, Patent infringement involving laser printer cartridges
18. 2007, **Allen, Allen, Allen and Allen**, Ilie Pop v. Safeway Services, Inc, et. al.
19. 2009, Cooley Godward Kronish LLP, **SwimWays Corporation**, Patent infringement case involving a pop-up pool
20. 2009, Cooley Godward Kronish LLP, **SwimWays Corporation**, Patent infringement case involving a canopy chair
21. 2009-11, **Lexmark International** (represented by Banner and Witcoff) v. Ninestar Image Co., Ltd, et. al., (and 23 other respondents), In the Matter of Certain Toner Cartridges and Components Thereof, ITC Investigation No. 337-TA-740 (resulted in a General Exclusion Order)
22. 2011, Advanced Cartridge Technologies (ACT) v. **Lexmark International**, (represented by Banner and Witcoff), Case No.: 8:10-cv-00486-SDM-TGQ
23. 2011, Benedetto v. **Volusia County**, FL, Case No.: 2010-33186-CICI, product liability investigation involving a beach wheelchair
24. 2012-13, **Lexmark International, Inc.** (Represented by Banner and Witcoff, LTD, v. Ink Technologies Printer Supplies, LLC, et al. Case Reference: Civil Action No. 1:10-CV-564-MRB
25. 2013, **180s** (represented by Cooley LLP) v. Costco and SM Global, patent infringement case involving ear muffs, Client Matter No. 078221-255
26. 2014, **Springfree Trampoline, Inc.**, (Represented by Fish and Richardson) v. Vuly Trampolines Pty. Ltd., ITC Investigation No. 337-TA-908
27. 2014-15, Valeda Company LLC, (D/B/A Q'straint), and, Sure-Lok, International, LLC, V. **American Seating Company**, (represented by Clark and Brody) CASE NO. 13-60824-CIV-Dimitrouleas/Snow
28. 2014-15, JumpSport, Inc. v. **Springfree L.P., et al.**, (Represented by Fish and Richardson) Civil Action No. 6:13-cv-929 (E.D. Tex.) and **Springfree L.P., et al.** v. JumpSport, Inc., Civil Action No. 4:14-cv-450 (E.D. Tex.), Inter Partes Review of United States Patent No. 6,053,845
29. 2014-15, **Esselte Corporation et al. Petitioners**, (represented by Goodwin Procter LLP) v. Sanford L.P. (d/b/a Dymo), Petition for Inter Partes Review of U.S. PATENT 6,152,623.
30. 2015-16, **AU New Haven, LLC and Trelleborg Coated Systems US, Inc.** (represented by Cooper & Dunham LLP) v. YKK Corporation Civil Action No. 15-CV-03411 (S.D.N.Y.)

31. 2015-16, **Reynolds Presto Products, Inc.** (represented by Greenberg Traurig LLP) v. Inteplast Group, Ltd. and Minigrip, LLC, ITC Investigation No. 337-TA-962
32. 2015-16, Diebold, Inc., et al. v. **Nautilus Hyosung Inc., et al.**, defendant (represented by Fish & Richardson P.C.), ITC Inv. 337-TA-972
33. 2016, **MTD Products Inc.** (represented by Calfee, Halter & Griswold LLP) v. The Toro Company and Exmark Manufacturing Company Inc., Civil Action No. 1: 15-cv-00766 (N.D. Ohio), Civil Action No. 1: 16-cv-00297 (N.D. Ohio), Inter Partes Review Case IPR2016-00194, Inter Partes Review Case IPR2016-00219
34. 2016, **SZ DJI Technology Co., Ltd. et al.** (represented by Wilson, Sonsini, Goodrich & Rosati) v. Yuneec International Co. Ltd. et al. Case No. 5:16-cv-595 BRO (KKx).
35. 2016, **SwimWays Corporation and Kelsyus LLC** (represented by Williams Mullen) v. Bestway (USA), Inc., Civil Action No. 1:16cv608
36. 2016, **Lippert Components Manufacturing, Inc. et al** (represented by Faegre Baker Daniels LLP) v. MORryde International Inc. et al,
37. 2017, **Sanofi-Aventis U.S. LLC et al**, Plaintiffs, (represented by Fish & Richardson P.C.). v. Merck Sharp & Dohme Corp., Defendant., 1:16-cv-00812
38. 2017, **Arris International plc., et al**, Complainant (represented by Fish & Richardson P.C.) v. Sony Corp., Respondents: Certain Consumer Electronic Devices, Including Televisions, Gaming Consoles, Mobile Phones and Tablets, and Network-Enabled DVD and Blu-Ray Players, ITC Inv. No. 337-TA-1060. ALJ: Dee Lord
39. 2017, **Traxxas LP**, Plaintiffs (represented by The Davis Firm, PC) v. Hobbico, Inc., et al, No. 2:16-CV-768 (E.D. Texas)
40. 2017, **The Lincoln Electric Company**, Plaintiffs (represented by Calfee, Halter & Griswold), v. Harbor Freight Tools USA, Inc., Defendant, Case No. 1:17-CV-02329.
41. 2018, **Caterpillar**, Plaintiffs (Finnegan, Henderson, Farabow, Garrett & Dunner, LLP) v. Wirtgen GmbH, et. al., In the Matter of Certain Road Construction Machines and Components Thereof, ITC Investigation No. 337-TA-1088. ALJ: Dee Lord
42. 2018, **Delta Faucet Company**, Plaintiff (represented by Faegre Baker Daniels LLP), v. Kohler Co. Case No. 1:17-CV-1222-SEB-DML
43. 2018, **Sanofi Aventis U.S. LLC**, Plaintiffs, (represented by Weil, Gotshal & Manges LLP) v. Mylan GMBH, Civil Action No. 2:17 -cv-09105 (SRC-CLW)
44. 2018, JumpSport, Inc. Plaintiff v. **Academy, Ltd D/B/A Academy Sports & Outdoors**, defendants (represented by Fish & Richardson P.C.), CIV. A. NO. 6:17-cv-414-RWS-JDL (Lead Consolidated Case)

Deposition and Court Testimony, 1995-2016

Year	Counsel	Opposing Counsel	Case Information (Client Shown In Boldface)	Plaintiff/ Defendant	Deposition/ Court Appearance
1995	Lowe, Price, LeBlanc and Becker		Virginia Panel v. Mac Panel, Civ. A. No. 93-0006-H, WD Virginia	Plaintiff	Deposition and Court Testimony. 1995, Richmond VA,
2004	Gilmer, Sadler, et al.,		Hicks v. Werner Ladder Co., Product liability investigation involving a ladder failure	Plaintiff	Deposition, December 2004, Blacksburg, VA
2005	Gilmer, Sadler, et al. Pulaski, VA		Garry Stoots v. Werner Co., et al. Product liability investigation involving a ladder failure	Plaintiff	Deposition, January 2005, Blacksburg, VA
2005	Fish & Richardson P.C	Faegre & Benson LLP	The Saunders Group, Inc. v. Comfortrac, Inc. and Care Rehab and Orthopaedic Products, Inc.	Defendant	Deposition, October 2005, Washington, DC
2006	Clark and Brody		American Seating Company v. USSC Group, Inc., Civil Action No. 1:01-CV-578	Plaintiff	Court Testimony, January 2006 Lansing, MI
2006	Banner and Witcoff		Lexmark v. Static Controls Corporation, Case No. 04-CV-84-KSF	Plaintiff	Deposition, November 2006, Washington, DC
2007	Banner and Witcoff, Chicago, IL		Lexmark v. Static Controls Corporation, Case No. 04-CV-84-KSF	Plaintiff	Court Testimony, May 2007, Frankfort, KY
2007	Allen, Allen, Allen and Allen	Morris & Morris	Ilie Pop v. Safeway Services, Inc, et. al.	Plaintiff	Deposition, August 2007, Richmond, VA
2011	Banner and Witcoff		ACT v. Lexmark Corporation Patent infringement involving laser printer cartridges.	Defendant	Deposition, July 12, 2011 Orlando, FL
2014	Fish & Richardson P.C	Finnegan, Henderson, Farabow, Garrett, & Dunner L.L.P.	Springfree Trampoline, Inc. v. Vuly Trampolines Pty. Ltd. ITC Investigation No. 337-TA-908	Complainant	Deposition, June 2014, Washington, DC

2014	Fish & Richardson P.C	Finnegan, Henderson, Farabow, Garrett, & Dunner L.L.P.	Springfree Trampoline, Inc. v. <i>Vuly Trampolines Pty. Ltd.</i> ITC Investigation No. 337-TA-908	Complainant	ITC Court Testimony, August 2014, Washington, DC ALJ: Thomas Pender
2014	Clark and Brody	Baker & McKenzie LLP	Valeda company LLC (d/b/a Q'straint), and Sure-lok, international, LLC v. American Seating Company	Defendant	Deposition, September 2014 Washington, DC
2016	Greenberg Traurig LLP	Dentons US LLP	Reynolds Presto Products, Inc. v. Inteplast Group, Ltd. and Minigrip, LLC, ITC Investigation No. 337-TA-962	Complainant	Deposition, January 2016 Washington, DC
2016	Greenberg Traurig LLP	Dentons US, LLP	Reynolds Presto Products, Inc. v. Inteplast Group, Ltd. and Minigrip, LLC, ITC Investigation No. 337-TA-962	Complainant	ITC Court Testimony, March 2016, Washington, DC ALJ: Theodore R. Essex
2016	Fish & Richardson P.C	Alston & Bird, LLP	Nautilus Hyosung Inc., v. Diebold Incorporated, ITC Investigation No. 337-TA-972	Respondents	Deposition, June, 2016
2016	Fish & Richardson P.C	Alston and Bird, LLP	Nautilus Hyosung Inc., v. Diebold Incorporated, ITC Investigation No. 337-TA-972	Respondents	ITC Court Testimony, August 2016, Washington, DC ALJ: Dee Lord
2016	Calfee, Halter & Griswold LLP	Robins Kaplin LLP	MTD Products Civil Action No. 1: 15-cv-00766 (N.D. Ohio), Civil Action No. 1: 16-cv-00297 (N.D. Ohio), Inter Partes Review Case IPR2016-00194, Inter Partes Review Case IPR2016-00219	Complainant	Deposition, December 8, 2016, Cleveland, Ohio
2016	Williams Mullen	McDermott Will & Emery LLP	SwimWays Corporation and Kelsys LLC v. Bestway (USA), Inc., Civil Action No. 1:16cv608	Plaintiff	Deposition, December 9, 2016, Washington, DC
2017	Williams Mullen	McDermott Will & Emery LLP	SwimWays Corporation and Kelsys LLC v. Aqua-Leisure Industries, Inc., Civil Action No. 2:16-cv-260	Plaintiff	Deposition, June 12, 2017, Washington, DC

2017	Cooper & Dunham LLP	Kilpatrick Townsend & Stockton LLP	AU New Haven, LLC and Trelleborg Coated Systems US, Inc. (represented by Cooper & Dunham LLP) v. YKK Corporation Civil Action No. 15-CV-03411 (S.D.N.Y.)	Plaintiff	Deposition, September 22, 2017, New York, NY
2017	Faegre Baker Daniels LLP	Masuda, Funai, Eifert & Mitchell, Ltd	Lippert Components Manufacturing, Inc., and Backsaver International, Inc. D/B/A Gorilla-Lift, v. MORryde International Inc. et al., Case No. 3:16-cv-00264-TLS-MGG	Plaintiff	Markman Hearing Court Testimony, October 26, 2017, South Bend, Indiana
2017	Fish & Richardson P.C	Quinn Emanuel Urquhart & Sullivan, LLP	Sanofi-Aventis U.S. LLC et al, Plaintiffs, v. Merck Sharp & Dohme Corp., Defendant., 1:16-cv-00812	Plaintiff	Deposition, December 19, 2017, New York, NY
2018	Calfee, Halter & Griswold LLP	Quinn Emanuel Urquhart & Sullivan, LLP	Lincoln Electric Company , et al. Plaintiffs, v. Harbor Freight Tools USA Inc., Defendants, CASE NO. 1:17-CV-02329	Plaintiff	Deposition, February 22, 2018, Cleveland, OH
2018	Fish & Richardson P.C	Quinn Emanuel Urquhart & Sullivan, LLP	Sanofi-Aventis U.S. LLC et al, Plaintiffs, v. Merck Sharp & Dohme Corp., Defendant., 1:16-cv-00812	Plaintiff	Deposition, April 13, 2018, New York, NY
2018	Finnegan, Henderson, Farabow, Garrett & Dunner, LLP	Sterne, Kessler, Goldstein & Fox, P.L.L.C	Caterpillar v. Wirtgen GmbH, et. al., In the Matter of Certain Road Construction Machines and Components Thereof, ITC Investigation No. 337-TA-1088	Complainant	Deposition, May 10, 2018, Washington, DC
2018	Fish & Richardson P.C	Quinn Emanuel Urquhart & Sullivan, LLP	Sanofi-Aventis U.S. LLC et al, Plaintiffs, v. Merck Sharp & Dohme Corp., Defendant., 1:16-cv-00812	Plaintiff	Court Testimony, U. S. District Court, District of Delaware, May 29-31, 2018, Wilmington, DE

2018	Finnegan, Henderson, Farabow, Garrett & Dunner, LLP	Sterne, Kessler, Goldstein & Fox, P.L.L.C	Caterpillar v. Wirtgen GmbH, et. al., In the Matter of Certain Road Construction Machines and Components Thereof, ITC Investigation No. 337-TA-1088	Complainant	Deposition, July 24, 2018, Washington, DC
2018	Finnegan, Henderson, Farabow, Garrett & Dunner, LLP	Sterne, Kessler, Goldstein & Fox, P.L.L.C	Caterpillar v. Wirtgen GmbH, et. al., In the Matter of Certain Road Construction Machines and Components Thereof, ITC Investigation No. 337-TA-1088	Complainant	ITC Court Testimony, September 25 and 26, 2018, Washington, DC, ALJ: Dee Lord
2018	Weil, Gotshal & Manges LLP	Wilson, Sonsini, Goodrich & Rosati	Sanofi-Aventis, Plaintiffs v. Mylan GmbH, Biocon Ltd., Defendant, C.A. No. 17-cv-09105-SRC-CLW	Plaintiff	Deposition, October 30, 2018, Washington, DC

General Consulting Experience:

- 1981 Gator Hydrostatics, Inc., Columbia, Tennessee. Material selection and heat-treatment specification for sawmill equipment.
- 1988-92 Milliken and Co., Spartanburg, SC. Various studies and design work involving textile equipment.
- 1990 Babcock and Wilcox, Inc., Lynchburg, VA. Design of a manipulator for maintenance of nuclear power plant steam generators.
- 1992 Industrial Drives, Radford Va., Analysis and redesign of a sorting mechanism.
- 1992 Department of Energy, Review panel on robotics technology.
- 2002 Fitness Quest, prospective product evaluation
- 2011-12 Swimways Corporation, product testing
- 2017-18 Gulf Coast State College, Panama City, FL, Consultant supporting research and development opportunities and educational programs in design and automation

December 7, 2018 TLR

APPENDIX B

(Screenshot A): Video at 00:00: Before Rotor Blade Installation



(Screenshot B): Video at 00:15: Counterclockwise Rotor Blade correctly installed



(Screenshot C): Video at 00:25: Clockwise Rotor Blade correctly installed



(Screenshot D): Video at 00:35: Clockwise Rotor Blade incorrectly installed on Counterclockwise shaft (black hub blade on silver tipped shaft)



(Screenshot E): Video at 00:51 Counterclockwise Rotor Blade incorrectly installed on Clockwise shaft (silver hub blade on black tipped shaft)



(Screenshot F): Video at 01:24 showing Phantom 3 supported (lifted) by rotor blades, showing they are securely attached

