UNITED STATES PATENT AND TRADEMARK OFFICE

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BEFORE THE PATENT TRIAL AND APPEAL BOARD

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SZ DJI TECHNOLOGY CO., LTD.,
Petitioner

v.

AUTEL ROBOTICS USA LLC,
Patent Owner

_____

Case No. IPR2019-00343
Patent No. 9,260,184

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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 the 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. I understand that DJI petitions for IPR of claims 1-2, 5-9, and 11 of the '184 patent and requests that the United States Patent and Trademark Office ("USPTO") cancel claims 1-2, 5-9, and 11 of the '184 patent. I understand that the Patent Office has instituted an IPR proceeding to review the patentability of claims 1-2, 5-9, and 11 ("Challenged Claims") of the '184 patent in IPR2019-000343.

3. 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.

4. Specifically, I was asked to review, evaluate, and respond to DJI's Petition and supporting materials, including the Declaration of Dr. Alfred Ducharme (Ex. 1003). I was asked to provide my opinion as to the patentability of the Challenged Claims in view of the invalidity challenges made by DJI and Dr. Ducharme.

5. 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

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

7. 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.

8. 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).

9. 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).

10. 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.

11. 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).

12. 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.

13. 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.

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

15. 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

16. 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

17. 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.

18. 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.

19. 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.

20. 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

21. I have reviewed the exhibits provided by Dr. Ducharme and DJI and reference the following documents in connection with this Declaration:

Exhibit	Description
DJI-1001	U.S. Patent No. 9,260,184
DJI-1003	Declaration of Dr. Alfred Ducharme
DJI-1004	Microdrones User Manual for md4-200 (“Microdrones”)
DJI-1006	U.S. Patent Publication No. 2014/0263823 to Wang
DJI-1008	Alibaba.com webpage featuring “LOTUSRC RC UFO T1000

	with GPS RC Quadcopter" ("LotusRC"), archived by Internet Archive Wayback Machine
DJI-1010	U.S. Patent Publication No. 2015/0203192 to Slanker
DJI-1011	U.S. Patent No. 8,052,081 to Olm et. al.
Autel-2001	JP Application Publication H06-17511 ("Sasaki")
Autel-2002	Pages from https://thesmithfam.org/blog/2006/10/17/rc-plane-prop-saver/
Autel-2003	Pages from https://web.archive.org/web/20070301204327/https://thesmithfam.org/blog/2006/10/17/rc-plane-prop-saver/
Autel-2004	U.S. Patent No. 9,677,564
Autel-2005	Pages from https://twistedhobbys.com/prop-saver-bands-installation-tool/
Autel-2006	Claim Construction Order in ITC Investigation No. 337-TA-1133
Autel-2007	Pages from Webster's New College Dictionary
Autel-2008	Pages from New Oxford American Dictionary
Autel-2009	Pages from Expert Report of Dr. Juan J. Alonso in ITC Investigation No. 337-TA-1133
NA	IPR 2019-00343, Paper 7 ("Institution Decision")
NA	IPR 2019-00343, Paper 2, Petition

V. SUMMARY OF OPINIONS

22. It is my opinion, as set forth in detail in this declaration, that the Challenged Claims of the '184 patent are not unpatentable in view of the prior art cited by DJI and Dr. Ducharme in their IPR petition materials. Specifically:

A. Microdrones does not anticipate claims 1-2.

B. Microdrones does not render obvious claims 1-2.

C. Microdrones in view of Wang does not render obvious claims 5-6.

D. Microdrones in view of LotusRC does not render obvious claims 5 or 7.

E. Microdrones in view of LotusRC in further view of Slanker does not render obvious claim 8.

F. Microdrones in view of LotusRC in further view of Wang does not render obvious claim 9.

G. Microdrones in view of Olm does not render obvious claim 11.

VI. BACKGROUND REGARDING STATE OF THE ART

A. Description of the Relevant Art

23. 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 blade[1] 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.

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

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

Autel's EVO

25. 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.

26. 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.

27. Different mechanisms have been used in the prior art for attaching rotor blades to UAV motor shafts. For example, one prior art mechanism is a simple screw-on method where the blade is screwed on to a threaded drive shaft. For example, a Japanese publication ("Sasaki") describes such a design, as shown in figures 8 and 9 below from the Sasaki reference. (Ex. 2001 at Figures 8-9).

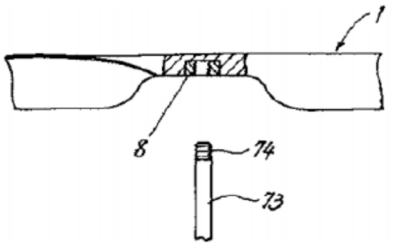

Fig. 8

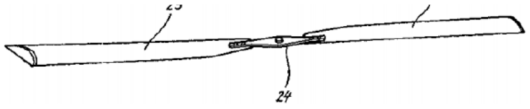

Fig. 9

28. In the design shown above, the central portion of the blade includes a threaded nut that screws onto the driveshaft, which is threaded at the distal end. Ex. 2001 at 1:49-2:4. This type of threaded design has drawbacks. First, it takes time to screw the blade all the way to the end of the threads. Second, as Sasaki explains, in a design of this type, it is necessary to ensure that a blade that rotates to the right uses a left nut and a blade that rotates to the left utilizes a right nut. Ex. 2001 at 2:5-16. In such an arrangement, during use, the directional force caused by rotation of the blade will have a tightening effect. Id. A drawback of this design is that the connections become tightened more than necessary, and the props are difficult to remove and replace. Ex. 2001 at 2:9-16. Third, in designs of this type, it is possible

to install the wrong blade (e.g., clockwise) on the wrong driveshaft (e.g., counterclockwise) by misthreading the screw threads.[2]

29. Another blade attachment method, commonly known as a "prop saver", was well known to a POSA at the time of the invention of the '184 patent. Ex. 2002 depicts pages from the following website that I located: https://thesmithfam.org/blog/2006/10/17/rc-plane-prop-saver/.[3] Ex. 2002, which is dated October 17, 2006 on its face, depicts and describes a prop saver design. It is consistent with my understanding based on my experience and knowledge that a POSA would have been aware of prop saver designs as early as 2006.

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[2] Multirotor UAVs typically use plastic or composite propellers for both the clockwise and counterclockwise blades. Because this material is soft, it can be relatively easy to thread a clockwise rotor blade on a motor shaft intended for a counter clockwise blade, and vice versa.

[3] I visited the following web archive website, which confirms that the website depicted in Ex. 2002 was available as early as 2007: https://web.archive.org/web/20070301204327/https://thesmithfam.org/blog/2006/10/17/rc-plane-prop-saver/. Ex. 2003 depicts pages from the web archive website that I visited.

30. The prop saver design creates a flexible and breakable connection between the prop (or blade) and the drive motor. A prop saver is intended to allow the prop to deflect and detach from the aircraft as a safety measure when the prop strikes an object. The goal of the prop saver design is primarily to prevent damage to the aircraft by making the connection between the prop to the drive motor flexible and relatively weak.

31. US Patent No. 9,677,564 states the following: "Another existing safety feature is a 'prop saver.' A prop saver typically includes a small rubber O-Ring attached to the propeller. The prop saver allows displacement of the propeller by 10-20° during an object strike before ejecting the propeller. The prop saver dampens the forces imparted on the propeller and object when contact occurs. After the propeller has displaced 10-20°, the propeller is ejected from the UAV, and UAV flight is discontinued. While the dampened object strike force resulting from the prop saver reduces damage to contact between the object and propeller, a prop saver may terminate UAV flight." Ex. 2004 at 1:37-47. In my opinion, this description is consistent with my understanding of a prop saver design, and with what a POSA would understand to be a prop saver design.

32. The prop saver design does not provide a rapid or convenient way to attach and detach a propeller or rotor. See, e.g., Ex. 2004, US Patent No. 9,677,564 at 6:57-59 ("Also, the magnetic propeller safety device may make a propeller easier

to attach and remove than the typical 'prop saver.'). The elastic bands (O-Rings) that secure the prop to the motor drive are difficult to install and easy to misplace. A POSA would be familiar with tools and techniques used to ease installation of a prop when using a prop saver. See, e.g., Ex. 2005. Ex. 2005 depicts pages from the following website that I located: https://twistedhobbys.com/prop-saver-bands-installation-tool/. These pages depict tools for installing "prop saver" O-Rings that a POSA would have been familiar with prior to the inventions of the '184 patent. Accordingly, the prop saver design sacrifices the benefits of ease of installation and removal, and a secure and rigid lock system, to obtain the benefit of reducing damage to the aircraft and drive system damage in the event of an object strike.

33. In addition, a prop saver design does not prevent the installation of the wrong prop blade (e.g. clockwise) on the wrong motor shaft (e.g. counterclockwise) because in a prop saver design, there is no difference between the O-Rings used for clockwise versus counterclockwise blades.

34. Accordingly, there was a need at the time of the '184 invention in the UAV industry for a convenient, quick-release, locking mechanism for UAV's that prevented the installation of the wrong rotor (e.g. clockwise) on the wrong motor (e.g. counterclockwise).

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

35. 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.

36. 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."

37. 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. 2006 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.

38. 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

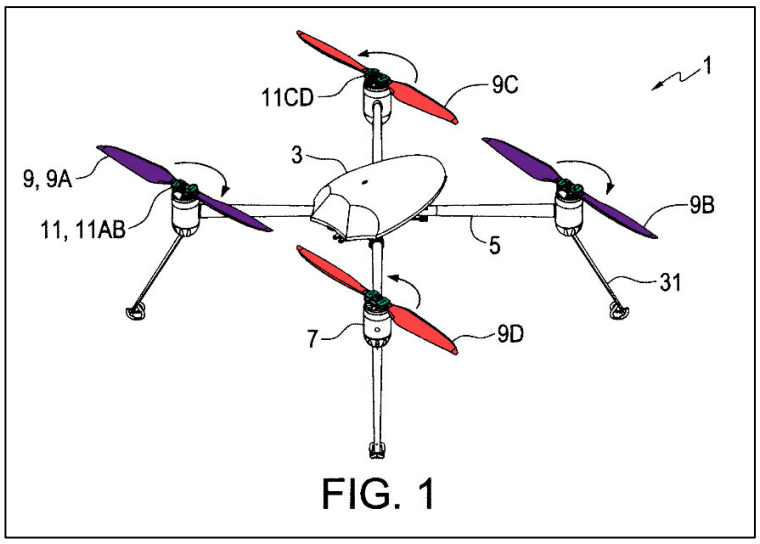
A. Background and Description of the '184 Patent

39. 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.

40. 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

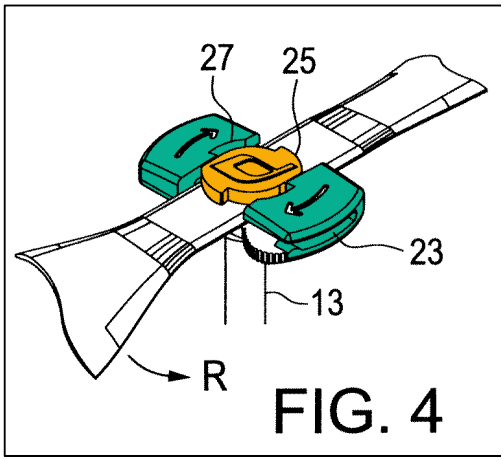
counterclockwise to only be able to lock to the motors configured to spin counterclockwise. Ex. 1001, '184 Patent, 1:55-2:7. As a result of this innovation, the rotor blades of the multi-rotor UAV "can be easily detached for transport o[r] storage, and cannot be placed on driveshafts rotating the wrong direction." Ex. 1001, '184 Patent, 2:16-18.

41. 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).

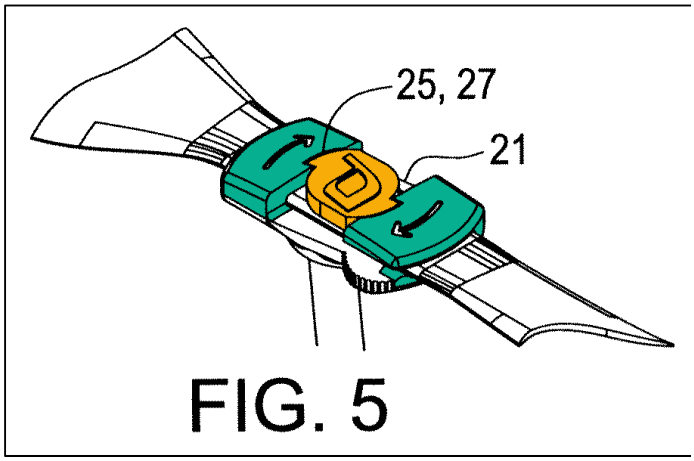


'184 Patent, Fig. 1

42. 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)

43. 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.

B. The ’184 Patent Claims

44. As described above, I have been asked to investigate the validity/patentability of claims 1-2, 5-9, and 11 of the ’184 patent. Claim 1 is an independent claim and claims 2, 5-9, and 11 are dependent claims that all depend, directly or indirectly, from claim 1.

45. Independent claim 1 is 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.

C. Claim Construction

46. 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.

47. 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. "lock mechanism"

48. In its Institution Decision, the Board found that the claimed "lock mechanism" may include other components. IPR2019-00343, Paper 7 at 16 ("[W]e agree with Petitioner's proposed construction of "lock mechanism" to the extent that it allows "components other than those specifically recited in the claims to [help] releasably attach the rotor blades"). I agree that the "lock mechanism" can include other components. Given Petitioner's arguments and the Board's institution decision, however, it is my opinion that additional clarification of the term may be necessary. The Board specifically noted that its construction was the only one needed for the purposes of its Institution Decision, and that the construction was not final. Id.

49. The plain meaning of lock is something that secures and prevents release. Ex. 2007 (Webster's New College Dictionary) ("…anything that fastens something else and prevents it from opening, turning, etc."); Ex. 2008 (New Oxford American Dictionary) ("a mechanism for keeping a door, lid, etc., fastened…").

50. As shown and described in ¶¶ 42 and 43 above, the lock mechanism described in the '184 patent rigidly secures the blade to the motor shaft such that the blade is prevented from removal during operation of the UAV. Although the blades are releasable, the '184 patent describes how, with respect to Figures 4 and 5, during use of the UAV, the force exerted by the rotation of the blade keeps the blade engaged in the slots of the lock mechanism. Ex. 1001 at 4:9-18 ("During operation the shaft lock portion 15A exerts a force in the direction of the arrows on the rotor blade to rotate same, and this force keeps the blade engaged in the slots 23.")

51. Accordingly, it is my opinion that the plain and ordinary meaning of "lock mechanism" in the context of the '184 patent is an apparatus that secures the rotor blade to the driveshaft and prevents the release of the rotor blade during operation.

2. "shaft lock portion" and "blade lock portion"

52. The claimed lock mechanism includes a "shaft lock portion" and "blade lock portion". Ex. 1001 at claim 1.

53. Figure 9 of the patent specification illustrates a top view of the shaft lock portion 15A and blade lock portion 17A. Ex. 1001 at Figure 9. The specification explains that in Figure 9, the blade is ready for engagement. Ex. 1001, '184 patent at 2:58-60. The specification then explains that the lock mechanism is "formed" when the blade is rotated into the recesses of the shaft lock portion. Ex.

1001, '184 patent at Figure 10, 2:61-62, 4:23-26, and 4:38-40. The locking function of the lock mechanism is accomplished by the interaction of the shaft lock portion and blade lock portion. Ex. 1001, '184 patent at 4:19-40. Accordingly, it is my opinion that a POSA would understand that the shaft lock portion and the blade lock portion of the '184 patent must perform a locking function.

54. This is consistent with the inventor's use of the word "lock" in the claim terms "shaft lock portion" and "blade lock portion". In other words, the "shaft lock portion" is the portion of the shaft that locks. It must perform a locking function based on the plain meaning of the term.

55. Although the Board has indicated that the claimed lock mechanism can include additional components, this does not change the plain meaning of the terms, and the disclosure of the patent specification, which only depicts shaft lock portions and blade lock portions that perform a locking function. Accordingly, although the lock mechanism can include other components, and those components may "help" attach the rotor blades, in my opinion the claimed shaft lock portion and blade lock portion must perform a locking function.

VIII. SUMMARY OF THE ALLEGED INVALIDATING PRIOR ART

A. Microdrones

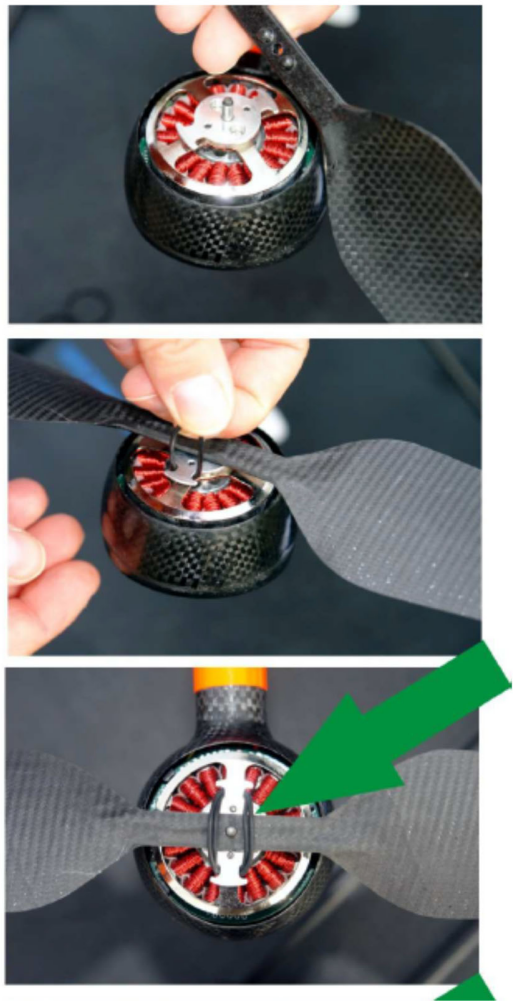
56. Microdrones states that it is a user manual for a UAV product. Ex. 1004 at 001. Dr. Ducharme states that it is his understanding that Microdrones is prior art

to the '184 patent. Ex. 1003 at ¶ 39. I understand there may be a dispute about whether Microdrones is prior art. I have not been asked to render an opinion on the issue. I have been asked to render opinions based on the assumption that Microdrones is prior art.

57. Microdrones depicts a UAV with four driveshafts and propellers (or rotors). Ex. 1004 at 0032. Two of the propellers turn clockwise and two turn counter clockwise. Ex. 1004 at 0037. Each of the propellers has two knobs on the bottom of the center bar as depicted below. Microdrones at 0037.

58. The knobs align with two indentations (referred to as holds) in a mounting plate that fits over the driveshaft. Ex. 1004 at 0037. To assemble the rotor, a user places the prop, which has a hole in the center, over the driveshaft and on top of the mounting plate. Ex. 1004 at 0037. The knobs are designed to rest in the indentations on the mounting plate. Ex. 1004 at 0037. At this point, however, the prop blade is not secured to the mounting plate. It is just resting on the mounting plate and rotation of the drive shaft would eject the prop blade. Nothing in Microdrones indicates that the interaction of the knobs and the holds performs any

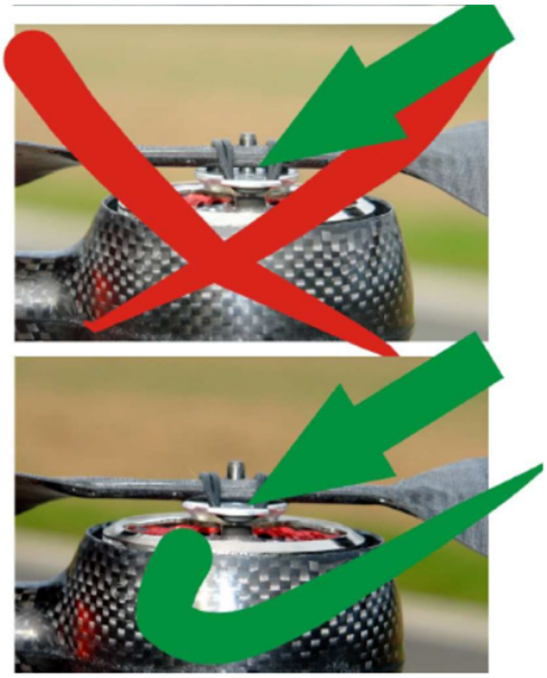
function of securing the prop to the driveshaft or motor. The prop is secured to the mounting plate with rubber O-Rings, as shown in the figures below from Figure 25 of Microdrones:



59. Microdrones utilizes a prop saver design, as described in ¶¶ 29-33 above.

60. Microdrones also states that "to avoid accidental misplacement, both directions of turning use individual distances between the knobs." Microdrones at 0037. The Microdrones design may help a user avoid accidental misplacement of a

clockwise prop on a counterclockwise driveshaft, but it does not *prevent* accidental misplacement. In other words, a user could place a clockwise prop on a counterclockwise driveshaft by placing the prop on the mounting plate of a counterclockwise motor. In that event, the knobs of the prop would not align with the holds on the mounting plate and the prop would not rest flush with the mounting plate. But a user could still secure the prop to the mounting plate because the Microdrones design uses O-Rings to secure the prop to the mounting plate. Microdrones specifically contemplates that such accidental misplacement may occur. Ex. 1004 at 0037 ("Make sure the center bar is level with the top of the mounting plate before you proceed"). Microdrones then depicts (in Figure 25) the difference between a misplaced prop (top image below) and a properly placed prop (bottom image below).



61. A POSA would understand from the context of the text on page 0037 of Microdrones, and the corresponding figures above, that the figure with the red "x" is depicting the wrong blade (e.g., clockwise) installed on the wrong motor (e.g., counterclockwise). As stated above, along with the figures, Microdrones explains that to avoid (not prevent) accidental misplacement, the distances between the knobs for clockwise versus counterclockwise blades is different. Microdrones then tells a user to, when mounting a rotor, "[m]ake sure that the center bar is level with the top of the mounting plate before you proceed." Ex. 1004 at 0037. Microdrones then depicts, with a large red "x", a rotor that is not flush with the mounting plate, and with a green check mark, a rotor that is flush with the mounting plate. Ex. 1004 at Figure 25. A POSA reading Microdrones would understand that Microdrones is

conveying to a user, with the figures and text on page 0037, that the configuration shown with the red "x" is a misplaced rotor blade, and that he or she should avoid such a configuration. Accordingly, Microdrones shows a rotor blade attachment mechanism that does not prevent the installation of the wrong rotor blade on the wrong driveshaft.

IX. THE CHALLENGED CLAIMS OF THE '184 PATENT ARE PATENTABLE OVER THE PRIOR ART

62. In my opinion, the Challenged Claims of the '184 patent are patentable, valid, and not anticipated or obvious over the asserted prior art.

A. Ground #1: Microdrones does not anticipate claims 1-2

63. Dr. Ducharme opines that claims 1 and 2 are anticipated by Microdrones. Ex. 1003 at ¶ 81. I disagree with Dr. Ducharme's opinion.

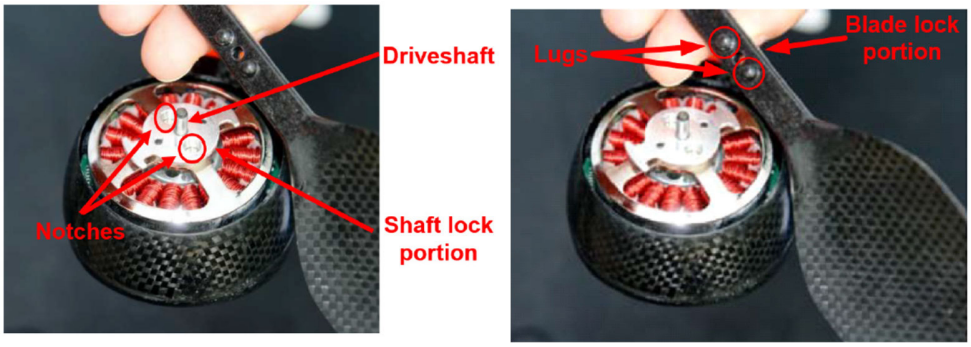
64. Claim 1 of the '184 patent requires, "each rotor assembly comprising a rotor blade releasably attached to a driveshaft by a lock mechanism." The plain meaning of "lock" requires that the lock mechanism create a secure lock to prevent the release of the rotor blade when in use in the locked position. The lock mechanism described in the '184 patent is a secure lock that rigidly secures the blade to the shaft. Ex. 1001, '184 Patent at 3:38-4:18. The patent specifically indicates that in the locked position and in use, the blade cannot be released from the shaft. Ex. 1001, '184 Patent at 4:13-18 ("During operation the shaft lock portion 15A exerts a force in the direction of the arrows on the rotor blade to rotate same, and this force keeps

the blade engaged in the slots 23."). As previously noted, Microdrones uses elastic O-Rings to releasably hold, but not lock, the prop to the driveshaft. It uses a prop saver design, which is intentionally made to ensure that the prop is not "locked" to the driveshaft. The prop saver design intentionally allows the prop to release from the shaft during operation in the event that it strikes an object. Accordingly, Microdrones does not disclose the claimed lock mechanism because it does not prevent the release of a rotor blade while the UAV is in use.

65. Claim 1 further requires, "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." As explained above, the shaft lock portion and blade lock portions must perform a locking function. This is consistent with the plain meaning of the term "lock" and the disclosure in the '184 Patent where the interaction of the shaft lock portion and the blade lock portion forms the lock mechanism that secures the blade to the shaft. Ex. 1001, '184 Patent at 3:38-4:18.

66. The portions of Microdrones relied on by Dr. Ducharme as the shaft lock portion and blade lock portion do not perform a locking function. Dr. Ducharme points to the rotor mounting plate as the "shaft lock portion" and the portion of the blade containing lugs as the "blade lock portion". Ex. 1003, at ¶¶

118-119. These alleged "lock portions" are shown in the below figures reproduced from Dr. Ducharme's report in ¶¶ 118 and 119.



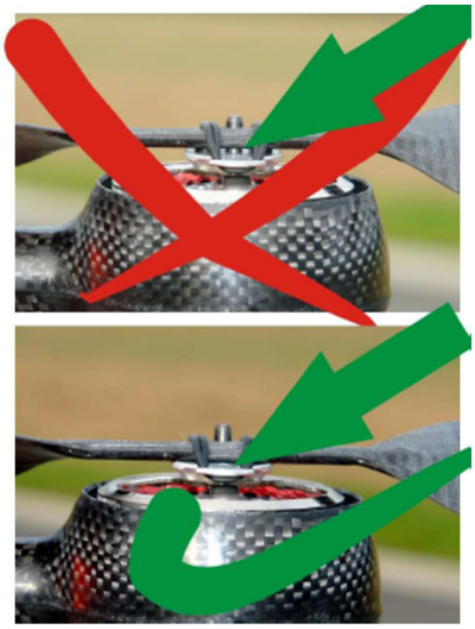
67. The "knobs and holds" described in Microdrones are features used "[t]o avoid accidental misplacement." Ex. 1004 at 0037. As previously described, when mounting the blades in Microdrones, a user places the blade over the driveshaft so that the blade is resting on the mounting plate. Ex. 1004 at 0037. The knobs are designed to rest in the holds so that the blade is flush with the mounting plate. Ex. 1004 at 0037. For this reason, the blade, knobs, mounting plate, and holds on the Microdrones device perform no locking function whatsoever. These features are present only to help match (not lock) the clockwise and counterclockwise rotating props with the clockwise and counterclockwise rotating drives, respectively. In Microdrones, the blade is held to the mounting plate with rubber O-Rings. Ex. 1004 at 0037. A POSA would understand that without the O-Rings, the blade would not be fastened in any way to the mounting plate or driveshaft. A POSA would also know that, in many other applications, the O-Ring prop saver design is used to attach

a prop to a rotor without any features to help determine which prop attaches to which drive. There is nothing in the Microdrones user's manual to suggest that the knobs and holds are engaged to serve a locking function. A POSA would understand that the hemispherical shape of the knobs and holds would be a poor choice for preventing relative rotation between the rotor and the motor shaft because the knob will ride up out of the hold as torque is applied. Without the O-Rings, the blade would be ejected from the drives as soon as they started to spin. Accordingly, because the mounting plate and the portion of the blade containing knobs perform no locking function, Microdrones does not disclose the limitation "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."

68. 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." I will refer to this limitation as the "engagement limitation". This limitation means that a clockwise rotor blade cannot be attached to a counterclockwise driveshaft and vice versa.

69. As mentioned previously in ¶ 23, if a UAV user attaches the wrong blade to the wrong driveshaft, the UAV will not function properly and could be damaged. 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.

70. As explained above in ¶¶ 60-61, Microdrones does not prevent a user from attaching the wrong blade to the wrong driveshaft. Microdrones specifically depicts this type of accidental misplacement in Figure 25 as shown below.



71. In the figure on top, the blade is misplaced on the wrong drive (e.g., a clockwise rotor blade is engaged with a counterclockwise drive). Since the O-Rings have been installed in these photos, the blade is now held to the drive and will stay in place until it strikes an object or it is removed by the user.

72. Dr. Ducharme asserts that in the top portion of the figure shown in ¶ 70 above (the configuration with the red "x"), the blade is not "engaged" with the mounting plate because the notches on the mounting plate do not "fully receive" the knobs on the blade. Ex. 1003 at ¶ 113. I disagree. As stated above, a POSA would understand the engagement limitation to mean that in the claimed UAV, a clockwise rotor blade cannot be fastened to a counterclockwise driveshaft. Microdrones clearly shows the misplacement of a blade, and thus, does not depict a UAV that meets the engagement limitation.

73. Contrary to Dr. Ducharme's opinion, there is no requirement in the engagement limitation that notches fully receive knobs on the blade. Claim 1 has an entirely different limitation related to engagement between notches on the shaft lock portion and lugs on the blade lock portion. Ex. 1001 at Claim 1 ("defining notches configured to engage corresponding lugs on the blade lock portion"). The attachment mechanism of Microdrones uses O-Rings. The O-Rings are non-directional, meaning they work to fasten a blade to a driveshaft regardless of the drive's rotation. Accordingly, Microdrones does not disclose a UAV that prevents a clockwise rotor blade from engaging with a counterclockwise drive.

74. Further, even if Dr. Ducharme were correct that the engagement limitation required that the lugs of the blade lock portion engage with the notches of the shaft lock portion, there is no requirement in the engagement limitation that the notches "fully receive" the knobs as suggested by Dr. Ducharme. In other words, a POSA would not conclude, based on the Microdrones figure below, that the knobs on the blade are not engaged with the notches on the mounting plate.

There is no way to conclude based on the photo above that the knobs on the blade are not in contact with the notches on the mounting plate.

75. Claim 1 further requires "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." As explained in ¶ 67 above, the knobs and holds of Microdrones do not perform a locking function and as explained in ¶¶ 69-71 above, Microdrones does not prevent accidental misplacement of the rotor blades. Accordingly, Microdrones does not disclose lock mechanisms that are specific to the direction of rotor blade rotation (i.e., a clockwise lock mechanism or a counterclockwise lock mechanism).

76. Claim 2 of the '184 Patent states, "The apparatus of claim 1 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, the blade lock portion comprising lugs with a configuration that is different than a configuration of the lugs on the blade lock portion of the clockwise lock mechanism." Claim 2 depends from claim 1, and it is therefore my understanding that claim 2 includes the limitations of claim 1. For all of the reasons previously stated, Microdrones does not anticipate claim 1, and thus cannot anticipate claim 2.

B. Ground #2: Microdrones does not render obvious claims 1-2

77. Dr. Ducharme asserts that a POSA would have modified Microdrones to arrive at claims 1 and 2 by integrally forming and attaching O-Rings "to either the driveshaft mounting plates or the rotor blades." Ex. 1003, at ¶ 133. Dr. Ducharme asserts that a POSA would integrate the O-Rings with the driveshaft mounting plates or the rotor blades to prevent a user from losing the O-Rings. Ex. 1003 at ¶ 133.

78. I disagree with Dr. Ducharme's opinion. As explained previously, the prop saver design of Microdrones specifically contemplates that the O-Rings may break during use in the event a prop strikes an object. Microdrones warns that the O-Rings can develop fissures. Ex. 1004 at 0037. It would be an impractical design to incorporate O-Rings, that would likely have to be replaced in the future, into the prop or driveshaft. In my opinion, users of a UAV are well aware of the potential

for O-Rings to break, given that they are specifically designed to stretch and/or break in the event of an object strike. As a result, users carry additional O-Rings, which are inexpensive. Dr. Ducharme states that having no O-Ring replacements available would be problematic to a user, but Dr. Ducharme's proposed "integral" design would not solve this problem. Even if the O-Ring were integral, it could still break, and a user would thus need to carry replacement O-Rings to plan for that possibility. And if an O-Ring break occurred with Dr. Ducharme's integral design, a user that wanted to continue flying the UAV would either have to (1) figure out how to remove the broken O-Ring that had been integrally formed with the UAV components and then install a separate O-Ring, (2) try to install a new O-Ring over the broken O-Ring, or (3) remove the broken O-Ring and reintegrate the O-Ring into the mounting plate or rotor blade. None of these options would be desirable for a user. The first two options would essentially return the UAV into the non-integral design. The third option would be more expensive and time consuming than replacing a separate O-Ring, and would likely not allow the user to quickly continue flight. For all these reasons, a POSA would not be motivated to modify Microdrones in the manner suggested by Dr. Ducharme.

79. Further, although Dr. Ducharme alleges that an O-Ring could be integrally formed with a blade or mounting plate, he cites no example where this has been done, and provides no analysis of how the integral formation would impact the

life or utility of the O-Rings during use. As previously noted, the prop saver design has been used on UAVs for many years. The fact that Dr. Ducharme has not cited an example of his "integral" O-Ring design supports my opinion that a POSA would not be motivated to modify Microdrones in that fashion.

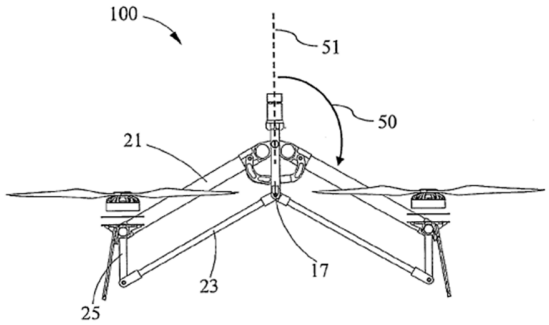
80. Even if, however, Dr. Ducharme were correct that a POSA would modify Microdrones to incorporate the O-Rings into the drive shaft or the rotor blades, such a design would still be a prop saver design, and Microdrones would not disclose the claimed lock mechanism for the reasons stated in ¶ 64 above. In addition, such a design would still allow a user to misplace a blade on the wrong lock mechanism (e.g., a clockwise rotor blade engaged in a counterclockwise lock mechanism) as described in ¶¶ 69-74 above. Accordingly, such a modification would not cure the defects of Microdrones with respect to those limitations and Microdrones alone would thus not render claims 1 and 2 obvious.

C. Ground #3: Microdrones in view of Wang does not render obvious claims 5 and 6

81. Claim 5 depends directly from claim 1, and claim 6 depends from claim 5. Accordingly, claims 5 and 6 include all of the limitations of claim 1. Dr. Ducharme does not rely on Wang for any of the limitations of claim 1. Ex. 1003, at ¶ 137. For all of the reasons previously stated, Microdrones does not disclose all of the elements of claim 1, and thus cannot render obvious claims 5 and 6 in combination with Wang.

82. There is also a lack of motivation to combine Microdrones and Wang. Dr. Ducharme opines that a POSA would be motivated to replace the landing gear used on Microdrones with the leg arrangement of Wang because, "legs attached to the rotor assembly instead of the central main body and that extend downward and away from the rotor allows for a wider support base and ensures more stability for a UAV when landing on a variety of surfaces…." Ex. 1003 at ¶ 143. Dr. Ducharme fails to point out that the landing gear of the Microdrones UAV could be extended out to create a wider base of support without attaching the legs to the rotor assemble and without angling the leg downward and away. More importantly, Dr. Ducharme fails to note that the elongated spindle-like legs of Wang are incompatible with the landing gear used in Microdrones. As shown in the image below taken from the cover of the Microdrones manual, Microdrone uses skids rather than legs as landing gear. These are the same type of ski-shaped skids that are often found on conventional helicopters. These skids curve up on one end (the end in the direction of forward flight as indicated by the orange arm and camera pointed in that direction).

A POSA would understand that the curved ski-shaped skids used on Microdrones are designed to allow the UAV to land and take off with forward motion. The upwardly curved front portion of the skids allows the UAV to slide along the ground slightly without catching. As shown in the Fig. 4 of Wang (reproduced below), the UAV disclosed in Wang is designed to land and take off with straight vertical motion and is unable to land or take off while moving forward. This is because the spindle-like legs would catch on any discontinuities on the ground (tall grass, uneven terrain) and cause the drone to tip forward.



Ex. 1006 at Figure 4. The same is true of the legs in LotusRC (as discussed in Ground #4 below):

Ex. 1003 at ¶ 152; Ex. 1008 at 004.

83. In my opinion, Microdrones teaches away from the point contact type of landing gear disclosed in Wang and LotusRC. Weight is a known, important consideration in UAVs. I note that the landing gear used in Microdrones could have easily been made lighter by eliminating the curved portion of the skid or even by eliminating the horizontal skid members entirely. Since minimizing weight is a major factor in designing UAVs, the curved skids used on the Microdrones UAV are clearly an important and intentional design choice.

D. Ground #4: Microdrones in view of LotusRC does not render obvious claims 5 and 7

84. Claim 5 depends directly from claim 1, and claim 7 depends from claim 5. Accordingly, claims 5 and 7 include all of the limitations of claim 1. Dr. Ducharme does not rely on LotusRC for any of the limitations of claim 1. Ex. 1003,

at ¶¶ 148, 151. For all of the reasons previously stated, Microdrones does not disclose all of the elements of claim 1, and thus cannot render obvious claims 5 and 7 in combination with LotusRC.

85. Additionally, for all the reasons I discussed above with respect to Dr. Ducharme's proposed combination of Microdrones and Wang, a POSA would not be motivated to replace the curved skids in Microdrones with the spindle-like legs in the LotusRC.

E. Ground #5: Microdrones in view of LotusRC in further view of Slanker does not render obvious claim 8

86. Claim 8 indirectly depends from claim 1. Accordingly, claim 8 includes all of the limitations of claim 1. Dr. Ducharme does not rely on LotusRC or Slanker for any of the limitations of claim 1. Ex. 1003, at 163. For all of the reasons previously stated, Microdrones does not disclose all of the elements of claim 1, and thus cannot render obvious claim 8 in combination with LotusRC and Slanker.

87. Initially, I note that Slanker's system is designed for a commercial aircraft where just the landing gear typically weigh between "about 2 and 6 tons." Ex. 1010, Slanker at ¶ [0002]. Actuators are used to raise and lower the landing gear during flight, but a "spring counterbalance" helps to reduce the force in the actuators when the landing gear are being retracted. Ex. 1010 at ¶ [0003]. To the extent that a latch is disclosed at all in Slanker, it is described as "down piston gear lock" 146 that automatically engages the landing gear. Ex. 1010 at ¶ [0032]. The "down

piston gear lock" 146 is shown schematically only as an empty box in the patent figures – no details are disclosed. Ex. 1010 at Figure 2A. In the '184 patent, "the operator pivots the leg 31 against the bias force BF to the operating position shown in FIG. 16." Ex. 1001 at 5:13-14. Hence Slanker is an active system that uses actuators to automatically raise, lower and lock the landing gear, while the '184 patent discloses a passive system that allows the legs to be folded for storage. As previously noted, reducing weight and complexity are critical factors in the design of a UAV. A POSA would not look to the complex actuator-driven landing gear disclosed in Slanker to find an improved way to fold a UAV leg.

88. Additionally, for all of the reasons I discussed above a POSA would not be motivated to combine Microdrones and LotusRC. The addition of Slankar does nothing to remedy the deficiencies in Dr. Ducharme's arguments regarding the combination of Microdrones and LotusRC. If anything, attempting to add the biasing member from Slanker's retractable landing gear mechanism only serves to make the combination more illogical.

F. Ground #6: Microdrones in view of LotusRC in further view of Wang does not render obvious claim 9

89. Claim 9 indirectly depends from claim 1. Accordingly, claim 9 includes all of the limitations of claim 1. Dr. Ducharme does not rely on LotusRC or Wang for any of the limitations of claim 1. Ex. 1003, at 178. For all of the reasons

previously stated, Microdrones does not disclose all of the elements of claim 1, and thus cannot render obvious claim 9 in combination with LotusRC and Wang.

90. Additionally, for all the reasons I discussed above with respect to Dr. Ducharme's proposed combination of Microdrones and Wang and Microdrones and LotusRC, a POSA would not be motivated to replace the curved skids in Microdrones with the legs in Wang or LotusRC individually or collectively. Dr. Ducharme attempts to use Wang to improve on his proposed combination of Microdrones and LotusRC (which, as I explained above, is not logical) to achieve the Claim 9 limitation that recites "wherein the leg slopes downward and away from the body when in the operating position." A POSA would be even less motivated to replace the curved skids of Microdrones with legs that slope downward and away from the body. While the skids used in Microdrones are designed to allow forward movement during landing and takeoff, legs that slope downward and away from the body are even more likely than the vertical legs on LotusRC to create snag points and tip the UAV on landing with forward motion. As I noted previously, Microdrones teaches away from point contact landing gear and toward landing gear that allow some skidding motion during takeoff and landing.

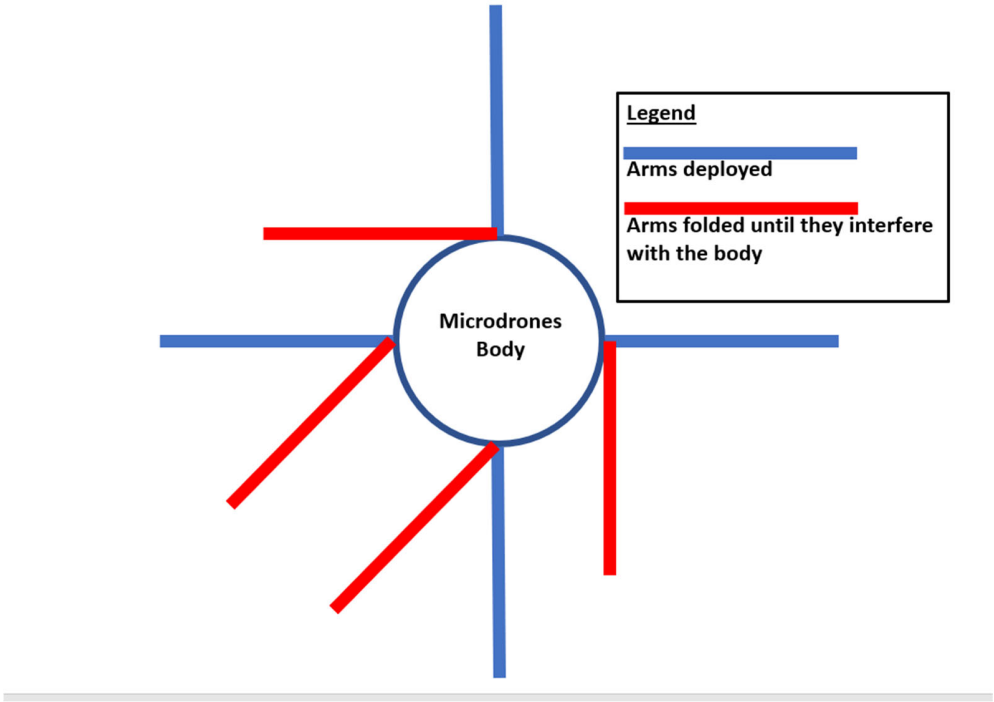
G. Ground #7: Microdrones in view of Olm does not render obvious claim 11

91. Claim 11 directly depends from claim 1. Accordingly, claim 11 includes all of the limitations of claim 1. Dr. Ducharme does not rely on Olm for

any of the limitations of claim 1. Ex. 1003, at 184. For all of the reasons previously stated, Microdrones does not disclose all of the elements of claim 1, and thus cannot render obvious claim 11 in combination with Olm.

92. In my opinion, a POSA would not have been motivated to combine Microdrones with Olm to achieve the claim 11 limitation: "wherein the arms are movably attached to the body such that the arms can be moved from a flying position, where the arms extend forward and rearward laterally outward from the body such that the arms are substantially equally spaced, to a folded stored position where at least one arm is substantially aligned with and adjacent to another arm." Dr. Ducharme shows the similarity between Olm '081 figure 13 and '184 patent figure 1 in attempting to show that a POSA would have known to apply the teachings of Olm '081 to Microdrones. Ex. 1003 at ¶ 185. But, as shown in an image from the Microdrones User's Manual below, the Microdrones UAV has a body that is circular in cross section. Ex. 1004 at 0001. Furthermore, the Microdrones md4-200 is, "a light weight vehicle constructed by carbon fiber," and the arms are formed integrally with the body. Ex. 1004 at 0032. A POSA would know that this manufacturing technique (laying up carbon fiber in a continuous structure) produces structures that are exceedingly light and strong.

93. It is not clear how Dr. Ducharme proposes to modify the structure of Microdrones md4-200 to include pivoting arms without losing the strength and weight advantages inherent in the design of Microdrones. Dr. Ducharme fails to address a number of other significant design challenges in trying to implement folding arms into the Microdrones UAV. For example, even assuming that the contiguous carbon fiber interface between the arms and the body could be replaced by a pivot, the arms on the Microdrones UAV would be unable to fold more than about 90 degrees before they began to interfere with the body. The illustration below highlights this problem.



94. The UAV disclosed in Olm '081 was designed from the outset with a slotted body arrangement that allows the arms to pivot within the shell of the body to achieve a folded stored position. Ex. 1011 at Figures 13,14. This would not be possible with Microdrones without significant modifications to the overall structure and design of the vehicle.

H. Secondary Considerations

95. In my opinion, there has been a need in the UAV industry for many years for UAV rotor blade attachment mechanisms, like the invention of the '184 patent, that can be quickly and easily detached and that prevent the misplacement of rotor blades. My opinion is supported by the opinions of Dr. Alonso, DJI's expert in ITC Investigation No. 337-TA-1133. Ex. 2009. In his expert report in that

proceeding, Dr. Alonso recognized that a POSA would have understood the need, since as early as the Sasaki reference, for simpler, faster, and mistake proof rotor blade attachment mechanisms. Ex. 2009 at Appendix A2, p. 26. ("In general, a POSITA would have understood the need to overcome the limitations of Sasaki to ensure simpler, more reliable, less error prone, and faster ways of attaching and detaching the propellers of a UAV.") Sasaki's application date is May 31, 1989. Ex. 2001, Sasaki at cover page. In my opinion, the length of time between that recognized need and the inventions in the '184 Patent, which has a priority date of May 15, 2013, represents a long-felt need in the industry for the inventions of the '184 Patent.

X. CONCLUSION

96. 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.

Date: 27 August 2019 

APPENDIX A

Autel Ex. 2010, p.51

Autel Ex. 2009, p.51

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

Society	Membership Grade
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 SUCCEEED, 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. 1ISSN: 0898-4697, 2014.

2. Hockley, C. J., Zuercher, T.A., Patel, H.V., Gamble, G.A., Kennedy, C.L. Coyle E.J., P.N. Currier, and C.F. Reinholtz, The Development of the ERAU Maritime RobotX Challenge Autonomous System, AUVSI North America, May 2014.

3. Jesse Hurdus, Andrew Bacha, Cheryl Bauman, Stephen Cacciola, Ruel Faruque, Peter King, Chris Terwelp, Patrick Currier, Dennis Hong, and Alfred Wicks and Charles Reinholtz, "VictorTango Architecture for Autonomous Navigation in the DARPA Urban Challenge," *AIAA Journal of Aerospace Computing, Information, and Communication*, Vol. 5, December 2008, DOI: 10.2514/1.40547.

4. Andrew Bacha, Cheryl Bauman, Ruel Faruque, Michael Fleming, Chris Terwelp, Charles Reinholtz, Dennis Hong, Al Wicks, Thomas Alberi, David Anderson,, Stephen Cacciola, Patrick Currier,, Aaron Dalton, Jesse Farmer, Jesse Hurdus, Shawn Kimmel, Peter King, Andrew Taylor, David Van Covern, Mike Webster, "Odin: Team VictorTango's entry in the DARPA Urban Challenge," *Journal of Field Robotics*, Vol. 25, No. 8, pg 467-492, 2008

5. David G. Schmale III, Benjamin R. Dingus, Charles Reinholtz, "Development and Application of an Autonomous Unmanned Aerial Vehicle For Precise Aerobiological Sampling Above Agricultural Fields," *Journal of Field Robotics*, Vol. 25. No. 3, pg 133-147, 2008, Copyright 2008 Wiley Periodicals, Inc.

6. Michael J. Furey, Charles F. Reinholtz, and Brian Vick, "Metal Transfer, Film Formation and Surface Temperatures on a Cam in an Automotive Engine," *Tribologia*, ISSN 0208-7774, June, 2007.

7. Leedy, B., Putney, J., Bauman, C., Cacciola, S., Webster, J. M., Reinholtz, C. F., "Virginia Tech's Twin Contenders: A Comparative Study of Reactive and Deliberative Navigation," *Journal of Field Robotics*, 23(9), 709-727, September, 2006.

8. Gombar, B., Terwelp, C., Fleming, M., Wicks, A. L. and Reinholtz, C.F., "JOUSTER: Joint Unmanned Systems Test, Experimentation and Research Facility," *International Test and Evaluation (ITEA) Journal*, December 2004/January 2005, pp. 9-13.

9. Stephen L. Canfield, R. Randall Soper, Charles F. Reinholtz, "Creating Highly Dexterous Manipulators Using Nonlinear Input Transmission," *ASME Journal of Mechanical Design*, Vol. 120, 1999.

10. Canfield, S. L., Soper, R. R., and Reinholtz, C. F., “Velocity Analysis of Parallel Manipulators by Truss Transformations,” *Mechanism and Machine Theory*, No. 34, 1999, pp. 345 – 357.

11. Roman, Chris and Reinholtz, C. F., “Robust Course-Boundary Extraction Algorithms for Autonomous Vehicles”, *IEEE Intelligent Systems*, Nov./Dec., 1998, pp.32-39.

12. Lee, H. Y., and C. F. Reinholtz, "Inverse Kinematics of Serial-Chain Manipulators," *ASME Journal of Mechanical Design*, Vol. 118, No. 3, September 1996, pp. 396 - 404.

13. Lee, H. Y., Fallon, J. B., Cordle, W. H., and Reinholtz, C. F., "Inverse Kinematic Analysis of a Mobile Underwater Inspection Robot," *Journal of Applied Mechanisms and Robotics*, Vol. 2, No. 3, July, 1995.

14. Canfield, S. L. and Reinholtz, C. F., "Development of an All-Revolute-Jointed Constant-Velocity Coupling," *Journal of Applied Mechanisms and Robotics*, Vol. 2, No. 3, July, 1995, pp.13-19.

15. Shooter, S. B., West, R. L. and Reinholtz, C. F., A Unified Approach to Teaching Analytical Cam Design Using Conjugate Geometry, *The International Journal of Mechanical Engineering Education*, Vol. 23, No. 2, April 1995, pp 145-156.

16. Voruganti, R. S., Dhande, S. G., and Reinholtz, C. F., "Symbolic and Computational Method for Design and Flat-Pattern Development of Bifurcation, Trifurcation- Type Transition Surfaces," *Transactions of the North American Manufacturing Research Institution of SME*, Volume XXII, pp 225-232, 1994.

17. 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," *Journal of Applied Mechanisms and Robotics*, Vol. 2, No. 2, April, 1994.

18. Tidwell, P. H., Bandukwala, N., Dhande, S. G., Reinholtz, C. F. and Webb, G., "Synthesis of Wrapping Cams," *Journal of Mechanical Design*, ASME Transactions, Vol. 116, No. 2, June, 1994, pp. 634-638.

19. Padmanabhan, B., V. Arun, and C. F. Reinholtz, "Closed-Form Inverse Kinematic Analysis of Variable Geometry Truss Manipulators," *Journal of Mechanical Design*, ASME Transactions, Vol. 114, No. 3, September, 1992, pp. 438-443.

20. Arun, V., C. F. Reinholtz, and L. T. Watson, "Application of New Homotopy Techniques to Variable Geometry Trusses," *Journal of Mechanical Design*, ASME Transactions, Vol. 114, No. 3, September 1992, pp. 422-427.

21. Voruganti, R. S., Dhande, S. G., and Reinholtz, C. F., "Symbolic and Computational Conjugate Geometry for the Manufacture of Helically Swept Surfaces," *Transactions of the North American Manufacturing Research Institution of SME*, Volume XX, pp 277-282, 1992.

22. Salerno, R. J., Reinholtz, C. F., and Dhande, S. G., "Kinematics of Long-Chain Variable Geometry Truss Manipulators," *Advances in Robot Kinematics*, pp. 179-187, Edited by S. Stifter and J. Lenarcic, Springer-Verlag Wien, New York, 1991.

23. Kosmatka, J. B., R. F. Fries, and C. F. Reinholtz,"Tension and Bending Stress Concentration Factors in U, V, and Opposed U-V Notches," *The Journal of Strain Analysis for Engineering Design*, Vol. 25, No. 4, 1990, 233-240.

24. Rogers, C. A., H. H. Mabie, and C. F. Reinholtz, "Design of Spur Gears Generated with Pinion Cutters," *Mechanism and Machine Theory*, Vol. 25, No. 6, 1990, pp. 623-634.

25. Mabie, H. H., C. A. Rogers, and C. F. Reinholtz, "Design of Spur Gears Cut by a Hob," *Mechanism and Machine Theory*, Vol. 25, No. 6, 1990, pp. 635-644.

26. Williams, II, R. L., and C. F. Reinholtz, "Proof of Grashof's Law Using Polynomial Discriminants," *Journal of Mechanisms, Transmissions and Automation in Design*, ASME Transactions, Vol. 109, No. 2, June, 1987, pp. 178-182.

27. Reinholtz, C. F., G. N. Sandor, and J. Duffy, "Branching Analysis of Spherical RRRR and Spatial RCCC Mechanisms," *Journal of Mechanisms, Transmissions and Automation in Design*, ASME Transactions, Vol. 108, No. 4, Dec. 1986, pp. 481-486.

28. Williams, II, R. L., and C. F. Reinholtz, "Mechanism Link Rotatability and Limit Position Analysis Using Polynomial Discriminants," *Journal of Mechanisms, Transmissions and Automation in Design*, ASME Transactions, Vol. 108, No. 4, Dec. 1986, pp. 562-564.

29. Myklebust, A., M. J. Keil and C. F. Reinholtz, "MECSYN-IMP-ANIMEC: Foundation for a New Computer-Aided Spatial Mechanism Design System," *Mechanism and Machine Theory*, Vol. 20, No. 4, 1985, pp. 257-269.

30. Reinholtz, C. F., S. G. Dhande, and G. N. Sandor, "Kinematic Analysis of Planar Higher-Pair Mechanisms," *Mechanism and Machine Theory*, Vol. 13, No. 6, 1978, pp. 619-629.

Notes, Review Articles, and Shorter Communications in Major Technical Journals

1. Fallon, J. B., and C. F. Reinholtz, "Simple Machine," short article published in the 1993 Edition of Academic American Encyclopedia, Deluxe Library Edition, Grolier, Inc., Vol. S, p. 316. Also published in the 1994 New Grolier Multimedia Encyclopedia, CD ROM Edition.

2. Fallon, J. B., and C. F. Reinholtz, "Machine," article published in the 1993 Edition of Academic American Encyclopedia, Deluxe Library Edition, Grolier, Inc., Vol. M, pp. 19-21. Also published in the 1994 New Grolier Multimedia Encyclopedia, CD ROM Edition.

3. Sandor, G. N., S. G. Dhande, and C. F. Reinholtz, discussion of "Reduction of Noise and Vibration in Roller Chain Drives," by S. W. Nicol and J. N. Fawcett, *Proceedings of the Institution of Mechanical Engineers*, Vol. 191 39/77, 1978.

4. Sandor, G. N., S. G. Dhande, and C. F. Reinholtz, discussion of "The Influence of Lubrication on Tooth-Roller Impacts in Chain Drives," by J. N. Fawcett and S. W. Nicol, *Proceedings of the Institution of Mechanical Engineers*, Vol. 191 21/77, 1978.

5. Reinholtz, C. F., review of the book Mechanics and Design of Cam Mechanisms, Pergamon Press, authored by F. Y. Chen, review published simultaneously in *Mechanism and Machine Theory*, Vol. 24, No. 4, 1985, and in *Shock and Vibration Digest*, Vol. 17, No. 12, 1985.

Books and Book Chapters

Mabie, H. H., and C. F. Reinholtz, Mechanisms and Dynamics of Machinery, 4th edition, with Solutions Manual, John Wiley and Sons, New York, 1987.

Teaching Excellence at a Research-Centered University, Edited by E. Scott Geller and Phil Lehman, Pearson Custom Publishing, Chapter 30: BRINGING THE BEST OUT OF STUDENTS: Teaching beyond the Classroom, 2006

Proceedings and Textbooks Edited

1. "Robotics, Spatial Mechanisms, and Mechanical Systems," Proceedings of the 22nd ASME Mechanisms Conference, DE-Vol. 45, September 1992, 644 Pages, Edited by G. Kinzel, C. Reinholtz, H. Lipkin, L. W. Tsai, G. R. Pennock and R. J Cipra.

2. "Mechanism Design and Synthesis," Proceedings of the 22nd ASME Mechanisms Conference, DE-Vol. 46, September 1992, 672 Pages, Edited by G. Kinzel, C. Reinholtz, G. R. Pennock, G. J. Wiens, R. J. Cipra, B. B. Thompson and T. R. Chase.

3. "Flexible Mechanisms, Dynamics, and Analysis," Proceedings of the 22nd ASME Mechanisms Conference, DE-Vol. 47, September 1992, 662 Pages, Edited by G. Kinzel, C. Reinholtz, H. Lipkin, L. W. Tsai, G. R. Pennock, R. J Cipra and B. B. Thompson.
4. Sandor, G. N., C. F. Reinholtz, and K. Soldner, errata to the book, *Mechanics and Design of Cam Mechanisms,* authored by F. Y. Chen, Pergamon Press, Inc., Elmsford, N.Y., 1982, 10 pages.

Conference Publications

1. Gudmundsson, Snorri, Vladimir Golubev, Sergey Drakunov, Charles Reinholtz, "Bio-Inspired Opportunistic Approaches in Energy-Conserving/Harnessing Flight-Path Modeling for UAS," AIAA Modeling and Simulation Technologies Conference, AIAA Aviation and Aeronautics Forum and Exposition 2016.
2. Christopher Hockley, Timothy Zuercher, Christopher Kennedy, Gene Gamble, Hitesh Patel, Patrick Currier, Eric Coyle, Charles Reinholtz, " System Architecture, Development and Results of the Embry-Riddle Aeronautical University Maritime RobotX Platform," Control ID#: 2028351, Session: UMS-02, Unmanned Systems: Technologies and Applications, AIAA Science and Technology Forum 2015.
3. Jesse Farmer and Charles Reinholtz, "Kinematic Analysis And Design of A Two-Body Articulated Robotic Vehicle," Proceedings of ASME 2009 International Mechanical Engineering Congress & Exposition, November 13-19, 2009, Lake Buena Vista, Florida, USA
4. Gerald R. Lane, Charles Reinholtz, Mohan Khrishnan, Mark J. Paulik, Nassif Rayess, "Articulated Unmanned Ground Vehicles (UGVs) Controlled with Complimentary Semi- & Autonomous Mobility Behaviors," NATO symposium on "Platform Innovations and System Integration for Unmanned Air, Land and Sea Vehicles", Florence, Italy," May 14-18, 2007.
5. Brett M. Leedy and Charles Reinholtz, "Developing a Fully Autonomous Vehicle for Virginia Tech's Entry in the DARPA Grand Challenge," National Instruments NI Week 2006, Austin Texas, (winner, Virtual Instrumentation Applications Paper Contest Best Control Paper Award).
6. Sean Baity, Charles F. Reinholtz and Alfred L. Wicks, "Kinematic Design of a Novel All-wheel Drive Multi-body Articulated Unmanned Ground Vehicle," AUVSI Unmanned Systems North America 2006.
7. Grant Gothing, Jesse Hurdus, Al Wicks and Charles Reinholtz, "Implementation of JAUS on a 2004 Cadillac SRX Using a Potential Fields Architecture", AUVSI Unmanned Systems North America 2006.
8. Benjamin Dingus, Elizabeth Hoppe, Jansen Lee, Nicholas Misyak, David Pape, Justin Ryan, Matthew Schivikas, Steven Ross Shake, Christopher Veraa, Rachael Ramirez, Charles Reinholtz, "Development of a Fixed-Wing Autonomous Aerial Vehicle at Virginia Tech," AUVSI UAV Competition Journal Paper, http://www.bowheadsupport.com/paxweb/seafarers/default.htm, June, 2006.
9. Ruél Faruque, Andrew Bacha, Charles Reinholtz, "Implementing a JAUS Design Process on Two Autonomous Robots for the Intelligent Ground Vehicle Competition," 6th Annual Intelligent Vehicle Systems Symposium, Grand Traverse Resort & Spa-Traverse City, MI, June, 2006.
10. Sean Baity, Jonathan Frentzel, Brett Gombar, Michael Fleming, Chris Terwelp, Al Wicks, Charles Reinholtz and Andrew Bacha, "Portable Wireless Site Instrumentation for Unmanned System Experimentation" AUVSI Unmanned Systems North America 2005, June 28-30, 2005, Baltimore, MD
11. Shane Barnett, Sean Baity, Ben Hastings, Chris Terwelp, Charles Reinholtz, Bill McBride,

Andrew Moore, Development of a Tow Capacity Test Device for Small Unmanned Vehicles, AUVSI Unmanned Systems North America 2005, June 28-30, 2005, Baltimore, MD

12. Gregg Vonder Reith, Ken Meidenbauer, Imraan Faruque, Chris Sharkey, Jared Cooper, Shane Barnett, Charles Reinholtz, "Development of an Autonomous Aerial Reconnaissance Platform at Virginia Tech," AUVSI UAV Competition Journal Paper, http://www.bowheadsupport.com/paxweb/seafarers/default.htm, June 14-18, 2005.
13. Andrew Bacha, Michael Fleming, Chris Terwelp, Charles Reinholtz and Al Wicks, "A Behavior Based Approach to Autonomous Lane Following," 5th Annual Intelligent Vehicle Systems Symposium, Grand Traverse Resort & Spa-Traverse City, MI, June 13-16, 2005
14. Sean Baity, Brett Gombar, Michael Fleming, Charles Reinholtz, "Design for the Intelligent Ground Vehicle Competition," 5th Annual Intelligent Vehicle Systems Symposium, Grand Traverse Resort & Spa-Traverse City, MI, June 13-16, 2005
15. Whittier, W. B., Reinholtz C. F., and Stubbs, M. D., "Single Degree-of-Freedom Morphing Wing: Design and Synthesis,", Proceedings of the ASME Design Engineering Technical Conference and Computers and Information in Engineering Conference, September 28-October 2, 2004, Salt Lake City, Utah, DETC2004-57019
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Mechanism and Control Law Development for an Autonomous Biplanar Bicycle," *Proceedings of the 6th National Applied Mechanisms and Robotics Conference*, Cincinnati, OH, December 13-15, 1999.

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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.

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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.

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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 l0th 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.

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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	Positions Held
ASME	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

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. Vuly Trampolines Pty. Ltd.* 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 Kelsyus 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 Kelsyus 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