

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

DYSON TECHNOLOGY LIMITED AND DYSON, INC.,
Petitioners,

v.

OMACHRON INTELLECTUAL PROPERTY INC.,
Patent Owner.

Case No. IPR2024-01317
U.S. Patent No. 11,910,983

**DECLARATION OF DR. KHALID SORENSEN IN SUPPORT OF
PATENT OWNER'S PRELIMINARY RESPONSE**

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APPENDIX LIST

Attachment	Description
Appendix A	Curriculum Vitae of Dr. Khalid Sorensen

PATENT OWNER'S EXHIBIT LIST

Exhibit	Description
2001	Declaration of Dr. Khalid Sorensen
2002	Comparison of Filter Bag, Cyclonic, and Wet Dust Collection Methods in Vacuum Cleaners, AIHAJ (62) (September/October 2001)
2003	Linden, Investigations into Cyclone Dust Collectors, Proceedings of the Institution of Mechanical Engineers (1949)
2004	Kim et al., Experimental Study of Particle Collection by Small Cyclones, Aerosol Science and Technology (1990)
2005	U.S. Patent No. 10,219,661

I. INTRODUCTION

A. Assignment

1. My name is Khalid Sorensen. I have been retained as an expert in this matter on behalf of Patent Owner Omachron Intellectual Property Inc. (“Patent Owner” or “Omachron”) to provide my independent opinions concerning the validity of U.S. Patent No. 11,910,983 (“the ’983 Patent” or “the Challenged Patent”).

2. I understand that Petitioners Dyson Technology Limited and Dyson, Inc. (“Petitioners” or “Dyson”) have petitioned for *inter partes* review (“IPR”) of claims 1–22 (“the Challenged Claims”) of the ’983 Patent based on several prior art references. Petitioners’ IPR Petition was supported by a declaration from Dr. Robert Giachetti. I have been asked to respond to certain positions of Petitioners and Dr. Giachetti.

3. More specifically, in this Declaration, I have been asked to respond to the following positions of Petitioners and Dr. Giachetti:

- a. whether independent claims 1 and 12 of the ’983 Patent are obvious over PCT Publication No. 2007/084543 to Butler et al. (“Butler”); and
- b. whether independent claims 1 and 12 of the ’983 Patent are obvious over German Patent Publication No. 1,680,208 to Rebel (“Rebel”) in combination with French Patent No. 1,094,603 to Martelliere (“Martelliere”).

B. Summary of Opinions

4. My opinions and the reasons for them are set forth in this Declaration. Briefly, and as explained in greater detail throughout this Declaration, my opinions can be summarized as follows:

- a. It is my opinion that neither Petitioners nor Dr. Giachetti have shown that Butler renders obvious claims 1 and 12 of the '983 Patent.
- b. It is my opinion that neither Petitioners nor Dr. Giachetti have shown that Rebel in combination with Martelliere renders obvious claims 1 and 12 of the '983 Patent.

5. All my opinions are made in view of the knowledge of a person of ordinary skill in the art ("POSITA") at the time of the claimed inventions.

C. Materials Considered

6. In preparing this Declaration, I have relied upon my education, experience, and training, as summarized herein and in my attached *curriculum vitae* (Appendix A). I have also considered the Petition and all exhibits cited therein, including the Declaration of Dr. Robert Giachetti (Ex1002).

D. Compensation

7. I am being compensated for my time at my standard rate of \$750 per hour, plus reimbursement of expenses. I do not have a financial interest in this action or its outcome, and my compensation in this matter is not based in any way on the substance of the opinions rendered here or the outcome of this case.

II. QUALIFICATIONS AND PROFESSIONAL EXPERIENCE

A. Professional Experience

8. I have over twenty (20) years of experience in designing and implementing industrial control, robotics, consumer products, and automation solutions across a broad range of industries. In 2008, I founded an automation and robotics company, and served as the company's Chief Technology Officer (CTO). The focus of my company was developing and deploying advanced motion control solutions for industrial cranes. During this time, I also developed control solutions for robotic automation and material handling systems. In 2013 my company was acquired by PaR Systems.

9. I served as an Engineering Fellow and CTO of PaR Handling Solutions, a business unit of PaR Systems, that supplies world-class, large-scale advanced robotic integration, crane control, advanced manufacturing automation, and nuclear handling solutions. Among my responsibilities as CTO at PaR Systems was to provide technical oversight of critical projects, lead in the creation of new and cutting-edge motion control, automation, and robotics technologies, direct research and development efforts, manage and protect the company's technology portfolio, and disseminate and facilitate the use of best-practice engineering methodologies.

10. In 2020 I founded Finity Engineering LLC. Finity Engineering provides design, analysis, and consulting services for robotic, automation, mechatronic, and consumer product applications.

11. Throughout my professional tenure, I have developed and provided technical oversight for the implementation of hundreds of technical solutions, many of which are deployed within high-profile facilities or in facilities of high-profile end users. These include, for example:

- | | | |
|-------------------------|--------------------|-----------------------|
| • Alcoa | • Grassland Dairy | • RR Donnelley |
| • Boeing | • Honda | • Southwire |
| • Cargill | • Hyundai | • Stoner |
| • Caterpillar | • Johnson Controls | • Ternium |
| • Chernobyl | • Kia Motors | • Transcontinental |
| • Cummins | • Larson Door | • Toyota |
| • CMC Metals | • Lockheed Martin | • Tyson Foods |
| • EA Sween | • Magna | • Universal Stainless |
| • Ford Motors | • McKesson | • Vantage Foods |
| • FreightCar
America | • Metalsa | • Ventura Foods |
| • Fukushima | • Novelis | • West Point Dairy |
| • Galvanisation | • NuCor | • Whiting |
| • General Motors | • NuScale | • Others. . . |
| • Gestamp | • Quad Graphics | |
| | • Quiver | |

12. In addition to the preceding, I am also the inventor and architect of ExpertoperatorTM, SafemoveTM, AutomoveTM, and CranevisionTM—four motion-control technologies used within the primary metals, automotive, aerospace, and heavy equipment sectors for enhancing crane safety, productivity, and ease-of-use. I also developed state-of-the-art on-line time-optimal trajectory synthesis software for flexible Cartesian machines. These industry-recognized motion control technologies were key drivers in the acquisition of my company by PaR Systems in 2013.

13. Throughout my career, I have been involved in the development, control, and implementation of machines that combine mechanical, electronic, software, control, and sensor technology. Accordingly, I have worked broadly with many different control, embedded control, sensor, actuator, and operator interface technologies. These include, for example, PLCs, embedded controllers, rotary, linear displacement and pressure sensors, electromechanical, hydraulic, and pneumatic actuators, optical sensing technologies including both 2D and 3D machine vision systems, touch-screen, push-button, gesture-based, and joystick operator interfaces, and vacuum generator and gripper technology, to name a few.

14. In addition to the preceding, part of my professional background includes work with consumer products. For example, I have developed haptic technology for consumer electronics, like smart watches and cell phones while providing services for the Advanced Technology and Programs (ATAP) group at Google. I have performed extensive analyses and experimentation on various personal transporters like Segways and hoverboards. Additionally, these devices have been the subject of engineering courses that I teach at the Georgia Institute of Technology related to advanced control of dynamic systems. I have also served as an expert witness for consumer technology involving autonomous vacuum cleaners and wet/dry vacuum cleaners.

B. Academia

15. I am an Adjunct Associate Professor at the Woodruff School of Mechanical Engineering at the Georgia Institute of Technology. I teach various engineering topics including Dynamics, The Design Process, Advanced Machine Control, PLC Programming, Mechatronics, Engineering Intellectual Property, Product Safety, and Warnings. I have given invited seminars at several academic and research institutions, in addition to those given at Georgia Tech. These institutions include the Massachusetts Institute of Technology, Kumoh National University of Technology, the Korea Atomic Energy Research Institute, Hyung Hee University, Huazhong University of Science and Technology, and others.

16. I have published dozens of refereed journal and conference articles and am a named inventor on multiple patents and patent applications, which are related to a wide variety of fields such as motion control, robotics, and automation. Many of my publications discuss the dynamics and control of highly dynamic systems, electromechanical actuation, and the dynamics of wheeled inverted pendulums.

17. In my professional role as a CTO, I have continued to direct research of graduate students at the Georgia Institute of Technology. These research efforts have investigated human factors in operator interface design, motion planning, swing control, non-linear actuation, collision avoidance, wheeled pendulum dynamics, and haptic feedback and control.

C. Education

18. I received my Ph.D. in Mechanical Engineering and M.S. in Mechanical Engineering from the Georgia Institute of Technology, in Atlanta, Georgia, in 2008 and 2005, respectively. I obtained a B.S. in Mechanical Engineering from Walla Walla University in 2002.

19. My *curriculum vitae*—which, among other things, details my degrees, employment history, teaching experience, publications, scholarly accomplishments, professional contributions, honors and awards, and fields of expertise—is attached to this Declaration as Appendix A.

III. LEGAL FRAMEWORK

20. I am a technical expert and do not offer any legal opinions. However, counsel for Patent Owner has informed me as to certain legal principles that I have applied in performing my analysis and arriving at my technical opinions in this matter.

A. General Claim Construction Principles

21. I understand that there are two types of claims: independent claims and dependent claims. I understand that an independent claim stands alone and includes only the limitations it recites. I understand that a dependent claim is a claim that depends on another claim. I understand that a dependent claim includes all of the limitations recited in the dependent claim as well as any limitations included in the corresponding independent claim.

22. I understand that before determining whether the Challenged Claims are invalid, the claims must be construed on a limitation-by-limitation basis. I understand that the Court may construe some terms or phrases as a matter of law. I understand that claim terms not construed by the Court are to be afforded their plain and ordinary meaning as used in the claims and as would be understood by a POSITA at the time of the invention. I understand that this person skilled in the art at the time of the invention is assumed to have read the claim terms in light of the entire patent record, including the other claims, the patent specification, and the patent prosecution history. I have interpreted the claim terms in the Asserted Patents in light of this understanding.

23. I understand that to properly understand the meaning of claim terms, one should first consider the intrinsic evidence, which includes the claim language itself, the patent specification, and the patent's prosecution, as well as any post-issuance history before the Patent Office. For example, the patent specification may show that the inventor used words or terms in a manner inconsistent with their plain and ordinary meaning. Specifically, I understand that where the specification reveals a special definition given to a claim term by the inventor that differs from the meaning it would otherwise possess, the inventor's lexicography governs. I understand that the prosecution history of the patent may also provide guidance in construing a claim term. For example, the prosecution history may show that the

patent applicant might have limited the scope of some or all of the claims during prosecution, either affirmatively or by implication.

24. I understand that if the intrinsic evidence is not conclusive regarding the meaning of a particular claim term, extrinsic evidence may also be used to determine its meaning. I understand that extrinsic evidence may be used, for example, to help determine what a person skilled in the art at the time of the invention would have understood the claim term to mean. Extrinsic evidence may include, for example, dictionaries, technical treatises and textbooks, journals, articles, or expert testimony.

B. Obviousness

25. I understand that for a claim to be invalid as obvious, the party asserting invalidity must identify prior art references that alone or in combination with other prior art references would have rendered the claim obvious to one of ordinary skill in the art at the time of the invention. I understand that the analysis of obviousness looks at 1) the scope and content of the prior art; 2) the differences between the claims and the prior art; 3) the level of ordinary skill in the art; and 4) secondary considerations of non-obviousness.

26. I understand that a single prior art reference can render a claim obvious where it would have been obvious to modify that reference to arrive at the patented invention. I understand that it is appropriate to look to the knowledge of a POSITA in assessing whether it would have been obvious to modify a single prior art

reference to produce the claimed invention. I also understand that a conclusion of obviousness may be based on a combination of prior art references. I understand that it may be helpful to identify a reason that would have prompted a person of ordinary skill in the relevant field to combine the elements in a way that the claimed invention does.

27. I understand that in determining whether a combination of prior art references renders a claim obvious, it may be helpful to consider whether there is some teaching, suggestion, or motivation to modify or combine the references and whether there would have been a reasonable expectation of success in doing so.

28. I understand that in evaluating whether patent claims are invalid as obvious, secondary considerations of non-obviousness are considered. I understand that the secondary considerations are considered with the balance of obviousness evidence in the record to act as a check against impermissible hindsight bias. I further understand that there must be a nexus between the merits of the claimed invention and the evidence of secondary considerations in order to give such considerations substantial weight in the determination of obviousness.

29. I understand that the burden of presenting evidence of secondary considerations is on the patentee. I also understand that the proponent of the evidence of secondary considerations bears the burden of showing that a nexus exists between the claimed features of the invention and the evidence offered to show non-obviousness.

30. I understand that the secondary considerations include commercial success, long-felt but unsolved needs, copying, praise, teaching away from the claimed invention by the prior art, unexpected results, industry acceptance, failure of others, and skepticism by experts.

IV. PERSON HAVING ORDINARY SKILL IN THE ART

31. I understand that claims are analyzed from the perspective of a person of ordinary skill in the art (“POSITA”) in the same field as the ’983 Patent at the time of the invention. I am also informed that several factors are considered in assessing the level of ordinary skill in the art, including 1) the types of problems encountered in the art; 2) the prior art solutions to those problems; 3) the rapidity with which innovations are made; 4) the sophistication of the technology; and 5) the education level of active workers in the field.

32. In my opinion, a POSITA in the art pertinent to the ’983 Patent as of its earliest priority date would have had at least a Bachelor’s degree in mechanical engineering or a closely related field, and have two years of experience in the design and implementation of vacuum/surface cleaning technology (or similar technology relating to fluid flow). Extensive experience in general mechatronic design and implementation could substitute for specific vacuum/surface cleaning technology experience. Similarly, significant professional experience could substitute for formal education.

33. I surpass this definition of a POSITA now and at the priority dates of the '983 Patent. Furthermore, through my roles as founder of an industrial motion control company, CTO at an automation and robotics technology company, and engineering professor at the Georgia Institute of Technology, I am familiar with the knowledge of a POSITA as of the priority dates of the '983 Patent. I am also able to opine on how a POSITA would have understood the disclosures and claims of the patent. Accordingly, my analysis of the '983 Patent has been based on this perspective of a POSITA as of the priority dates of the patent.

V. BACKGROUND AND TECHNOLOGY OF THE '983 PATENT

A. Overview of the '983 Patent

34. The '983 Patent issued on February 27, 2024, from an application filed June 2, 2022, naming Wayne Conrad as inventor.

35. The '983 Patent relates to “the field of surface cleaning apparatus,”¹ and, in particular, to “[a] surface cleaning apparatus compris[ing] a hand vacuum cleaner, a surface cleaning head and a rigid air flow conduit removably mountable between the surface cleaning head air outlet and the dirty air inlet of the hand vacuum cleaner.”² According to the '983 Patent, “[h]and vacuum cleaners or handvac[s]” were known and were “advantageous as they are lightweight and permit above floor

¹ '983 Patent (Ex1001) at 1:23–27.

² '983 Patent (Ex1001) at Abstract.

cleaning and cleaning in hard to reach locations.”³ The ’983 Patent seeks to improve on the prior art by providing a specific configuration and orientation of components, including a cyclone with an axis of rotation with specific orientation, and a pistol grip handle at rear portion of the hand vacuum cleaner.⁴

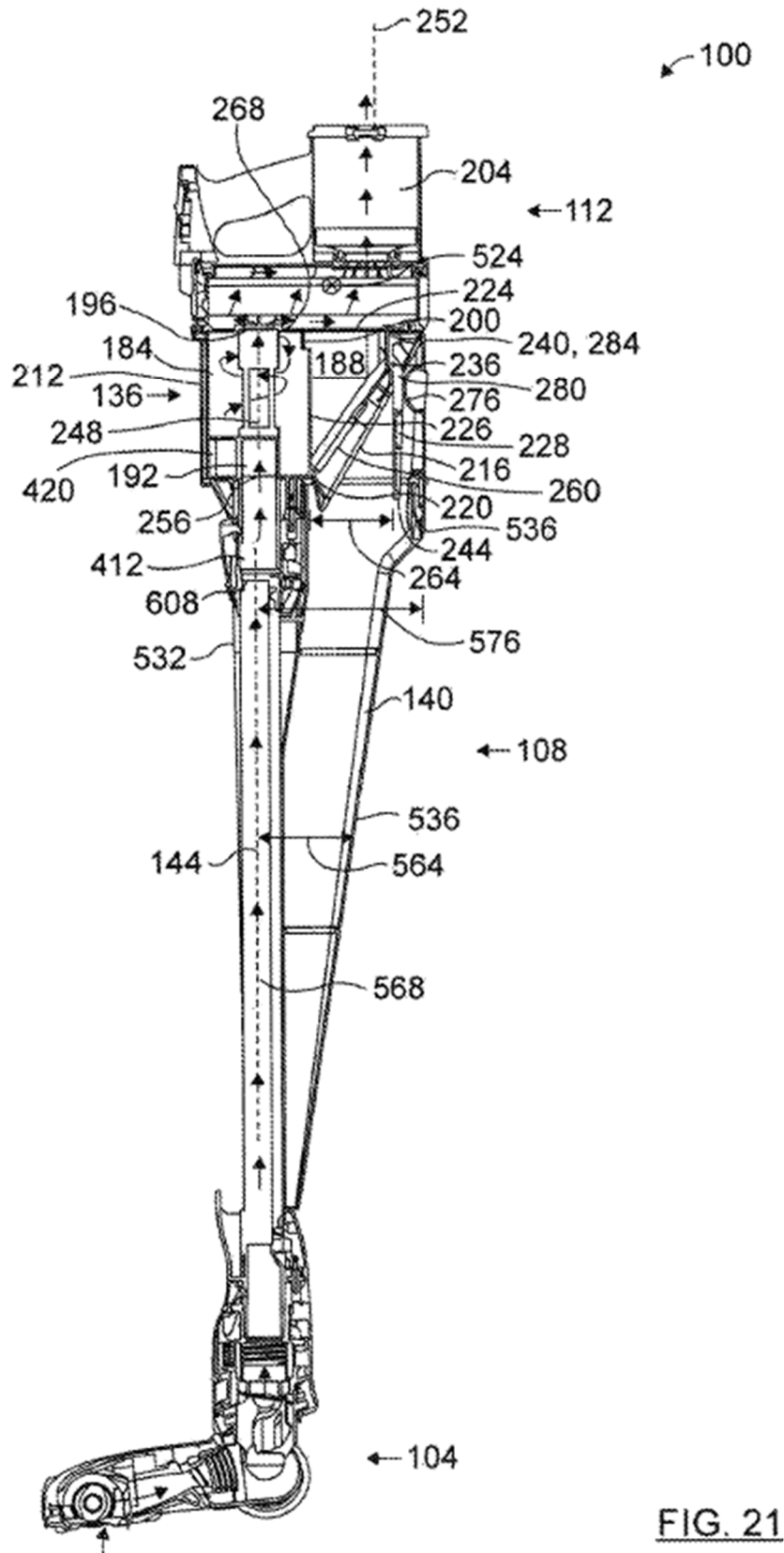
36. One such embodiment is the surface cleaning apparatus of Figure 21, shown below, and the related hand vacuum cleaner of Figure 22. One may observe that the cyclone axis 248 of handvac 112 is parallel to the suction motor axis 252. Moreover, the configuration is such that the cyclone axis would be generally horizontal if surface cleaning apparatus itself were positioned on a horizontal surface (*i.e.*, with the upper end (*i.e.*, top wall 212) above the lower end (*i.e.*, bottom wall 216).⁵ Additionally, the pistol grip handle is located toward the rear of the hand vacuum cleaner and is a “driving handle” for the surface cleaning apparatus.⁶

³ ’983 Patent (Ex1001) at 1:31–46.

⁴ ’983 Patent (Ex1001) at cl. 1.

⁵ See ’983 Patent (Ex1001) at 12:24–13:15, 18:33–44 for general description of Figure 21.

⁶ ’983 Patent (Ex1001) at 33:16–34:34.



B. '983 Patent Claims

37. I understand that Petitioners have challenged claims 1–22 of the '983 Patent. Because I was asked to limit my opinions in this Declaration to independent claims 1 and 12, the table below lists the text of those two challenged claims. For consistency, I have applied the same “Reference Number” for claim elements that Petitioners assigned in the Petition.

Claim Element	Claim Text
[1pre]	A surface cleaning apparatus comprising:
[1a.1]	(a) a hand vacuum cleaner having a front end having a dirty air inlet, a rear end, a clean air outlet, an upper end, a lower end,
[1a.2]	a cyclone unit comprising a cyclone chamber having a cyclone axis of rotation that extends in a forward/rearward direction, a suction motor and fan assembly having a suction motor axis of rotation and a pistol grip handle;
[1b]	(b) a surface cleaning head having a front end, a rear end, a dirty air inlet and a surface cleaning head air outlet; and,
[1c.1]	(c) a rigid air flow conduit which, when mounted to the surface cleaning head and the hand vacuum cleaner, extends between the surface cleaning head air outlet and the dirty air inlet of the hand vacuum cleaner,
[1c.2]	wherein the pistol grip handle has a pistol grip portion and an end that is mounted to an outer wall of the hand vacuum cleaner at a location rearward of the front end and forward of a rear end of the suction motor and

Claim Element	Claim Text
[1c.3]	wherein a plane that is transverse to the cyclone axis of rotation extends through the pistol grip portion and the hand vacuum cleaner at a location rearward of the front end and forward of a rear end of the suction motor,
[1c.4]	wherein the dirty air inlet of the hand vacuum cleaner is removably drivingly mountable to a downstream end of the rigid air flow conduit whereby when the hand vacuum cleaner is mounted to the downstream end of the rigid air flow conduit, the pistol grip handle is a driving handle for the surface cleaning apparatus, and
[1c.5]	wherein when the hand vacuum cleaner is positioned with the front end of the hand vacuum cleaner in front of the rear end of the hand vacuum cleaner and the dirty air inlet faces forwardly, the cyclone axis of rotation is generally horizontal.
[12pre]	A surface cleaning apparatus comprising:
[12a.1]	(a) a hand vacuum cleaner having a front end having a dirty air inlet, a rear end, a clean air outlet, an upper end, a lower end,
[12a.2]	a cyclone unit comprising a cyclone chamber having a cyclone axis of rotation that extends in a forward/rearward direction when the dirty air inlet faces forwardly, a suction motor and fan assembly having a suction motor axis of rotation and a pistol grip handle wherein the suction motor axis of rotation is generally parallel to the cyclone axis of rotation;
[12b]	(b) a surface cleaning head having a front end, a rear end, a dirty air inlet and a cleaning head air outlet; and,

Claim Element	Claim Text
[12c.1.i]	(c) a rigid air flow conduit which is mountable between the cleaning head air outlet and a hand vacuum cleaner air inlet, the rigid air flow conduit having a longitudinally extending conduit axis,
[12c.1.ii]	wherein, when the hand vacuum cleaner is mounted to the downstream end of the rigid air flow conduit, the handle is a driving handle for the surface cleaning apparatus and the longitudinally extending conduit axis of the rigid air flow conduit is parallel to the cyclone axis of rotation, and
[12c.2]	wherein the pistol grip handle extends generally radially away from an outer wall of the hand vacuum cleaner at a location rearward of the front end and forward of a rear end of the suction motor.

C. Summary of the Prosecution History of the '983 Patent

38. The application that issued as the '983 Patent (appl. no. 17/830,507, referred to herein as “the '507 application”) was filed on June 2, 2022. It is part of a chain of continuation and continuation-in-part applications, all claiming priority to a provisional application (no. 62/093,189), filed on December 17, 2014.

39. As filed, the '830 application had 23 claims, two of which (claims 1 and 12) were independent. On May 31, 2023, the examiner issued an Office Action rejecting all pending claims as being obvious over JP2014083241 to Mori in view of US 2006/0090290 to Lau or US 9,204,769 to Conrad. According to the examiner, Mori disclosed all limitations of the claims except for the “cyclone unit” limitations, including a cyclone axis of rotation that is generally horizontal. The examiner

pointed to Lau and Conrad for those limitations, stating that “it would have been obvious to one skilled in the art at the time of the invention to substitute the cyclone unit in Lau [or Conrad] for the separation assembly in the hand vacuum cleaner in Mori et al. since the cyclone unit in Lau [and Conrad] is used for the same purpose of separating dust particles from the air as the separation assembly in Mori et al.”

40. On August 29, 2023, in response to the Office Action, the applicant amended independent claim 1 to include limitation 1[d], which is reproduced above (relating to the pistol grip handle). The applicant argued to the examiner that Mori “does not disclose a pistol grip handle [that] has an end that is mounted to an outer wall of the hand vacuum cleaner.” The applicant also canceled claim 23.

41. Following the amendment, on October 23, 2023, the examiner issued a Notice of Allowance for claims 1–22. On December 27, 2023, the applicant filed an Amendment After Notice of Allowance, clarifying language of the claims as allowed. For example, in claim 1, the applicant added the underlined language: “a rigid air flow conduit which, when mounted to the surface cleaning head and the hand vacuum cleaner, extends between the surface cleaning head air outlet and the dirty air inlet of the hand vacuum cleaner.” On January 8, 2024, the examiner allowed the claims as amended. The '983 Patent issued on February 27, 2024.

VI. PRIOR ART VALIDITY ANALYSIS

42. It is my opinion that neither Petitioners nor Dr. Giachetti have shown that independent claims 1 and 12 of the '983 Patent are invalid as obvious. My bases and reasons for this opinion are provided below.

A. Summary of Invalidity Arguments for the '983 Patent

43. Petitioners and Dr. Giachetti present four grounds of invalidity for the Challenged Claims of the '983 Patent, as summarized in the chart below. The invalidity grounds are based on the following four prior art references:

- a. WO 2007/084543 to Dennis Butler et al. ("Butler");
- b. Chinese Patent Publication No. CN101061932 ("Jianan");
- c. German Patent Publication No. 1,680,208 ("Rebel"); and
- d. French Patent No. 1,094,603 to Martelliere ("Martelliere").

Ground	Claims	Basis
1	1–2, 4–10, 12–15, 17–21	Obviousness based on Butler
2	3, 10–11, 16, 21–22	Obviousness based on Butler and Jianan
3	1–2, 4–10, 12–15, 17–21	Obviousness based on Rebel and Martelliere
4	3, 10–11, 16, 21–22	Obviousness based on Rebel, Martelliere, and Jianan

44. I have been asked for this Declaration to provide opinions with respect to independent claims 1 and 12. Below is a summary of the three prior art references that are relevant for those claims of the '983 Patent. I then explain in detail why

Petitioners and Dr. Giachetti have not shown that either claim 1 or 12 is invalid as obvious on these bases.

1. Summary of Butler

45. International Publication No. WO 2007/084543, titled “Stair Cleaning Vacuum Cleaner,” to Dennis Butler et al. (“Butler”) was filed on January 17, 2007, and published on July 26, 2007.⁷ I have been asked to assume that Butler is prior art to the ’983 Patent.

46. Butler relates to a “novel vacuum cleaner adapted for cleaning in stairwells and other confined spaces.”⁸ Butler describes the different types of existing vacuum cleaners—including handheld, “upright and canister vacuum cleaners, wet extractors, stick vacuums, and electric brooms”—and how each vacuum is “better suited for some surfaces than others.”⁹ Butler explains that each of these existing vacuum types have shortcomings with respect to vacuuming stairs or other confined spaces.¹⁰ For example, Butler explains that “[s]tick vacuums are . . . typically just as long as a conventional vacuum cleaner, which makes them difficult to manipulate in enclosed stairwells, closets, and other confined spaces.

⁷ Butler (Ex1005) at Cover.

⁸ Butler (Ex1005) at 1:2–3.

⁹ Butler (Ex1005) at 1:5–10.

¹⁰ Butler (Ex1005) at 1:10–3:9; *see also id.* at 23:19–21.

This length also makes it difficult for the user to hold the grip located at the end of the handle when cleaning stairs.”¹¹ Butler also explains that “[h]andheld vacuums have been used as a substitute for upright, stick and canister vacuums for cleaning stairs and confined spaces, but such vacuums require the user to stoop, if not kneel, to clean.”¹² In view of these deficiencies Butler states that “there exists a need for an improved vacuum cleaner for cleaning raised and vertical surfaces, and particularly stair treads and risers.”¹³

47. To address shortcomings in the prior art, Butler discloses multiple embodiments of a vacuum cleaner specifically adapted for cleaning in stairwells and other confined spaces. The embodiments of Butler share common attributes:

- Butler’s vacuum cleaner “ha[s] a generally elongated housing having a first housing end and a second housing end, a rear grip located at the first housing end, and an air inlet located at the second housing end.”¹⁴
- In addition to the grip (handle) at the rear, “[t]he vacuum cleaner also includes a foregrip located on the housing between the rear grip and the air inlet. The foregrip is adapted to provide a user with multiple hand positions around the

¹¹ Butler (Ex1005) at 2:29–3:2.

¹² Butler (Ex1005) at 25:19-21.

¹³ Butler (Ex1005) at 3:10–12.

¹⁴ Butler (Ex1005) at 3:20–24.

perimeter of the housing.”¹⁵ To provide this flexibility, most embodiments of Butler include generally circular rear and foregrips.¹⁶

48. For example, in the preferred embodiment of Figure 1 (reproduced below), there is a “rear grip 106” attached at the opposite end of inlet nozzle 104. “Preferably, the rear grip 106 is generally circular in shape, and forms a loop that gives the user flexibility in selecting an ergonomic position in which to hold the rear grip 106.”¹⁷ In addition to the rear grip, “[t]he vacuum cleaner 100 also includes a foregrip 130 located between the rear grip 106 and the inlet nozzle 104.”¹⁸ The foregrip “includes various features to enhance the ergonomics and control of the vacuum cleaner 100,” including “a continuous loop-like shape that surrounds the vacuum cleaner housing 102, which allows the user to hold the foregrip 130 in virtually any annular location around the housing.”¹⁹ With this configuration, there is “improved flexibility in handling the device, and allows the user to rotate the housing to point the nozzle inlet 104 horizontally to clean surfaces such as stair treads, vertically to clean surfaces such as stair risers, or at any angle in between.”²⁰

¹⁵ Butler (Ex1005) at 3:28–4:1.

¹⁶ Butler (Ex1005) at 10:16–21, 11:21–12:16, Figs. 1, 2A, 5, 6.

¹⁷ Butler (Ex1005) at 10:16–21.

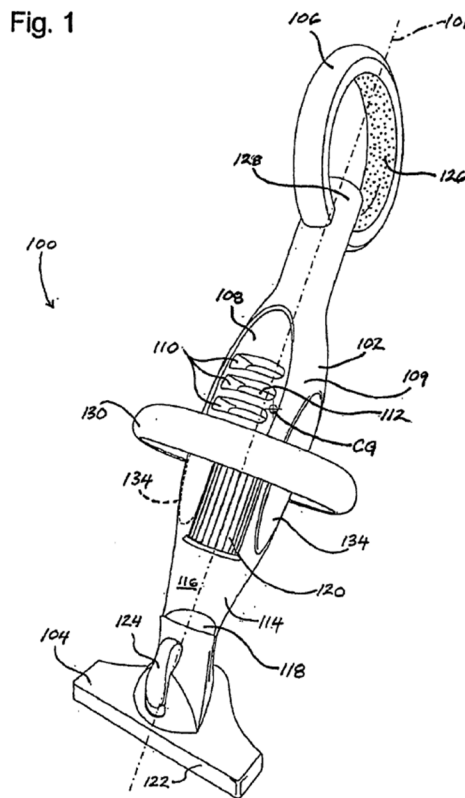
¹⁸ Butler (Ex1005) at 11:21–22.

¹⁹ Butler (Ex1005) at 12:3–10.

²⁰ Butler (Ex1005) at 12:7–16.

According to Butler, the dual handgrip configuration further allows a user to “apply significant pressure between the inlet nozzle 104 and the surface being cleaned.”²¹

In the preferred embodiment, “the foregrip 130 should generally surround the device’s center of gravity CG,” which promotes balance and comfort “regardless of the angular orientation.”²²



49. Although Butler describes various alternate handle arrangements,²³ there are not an unlimited number of handle arrangements disclosed in Butler. For

²¹ Butler (Ex1005) at 12:17–30.

²² Butler (Ex1005) at 13:1–19.

²³ See, e.g., Butler (Ex1005) at Figs. 3–8.

example, in all embodiments there is both a rear grip and a foregrip, and the same considerations of improving ergonomics for stairwell cleaning apply when determining the location and orientation of the grips.²⁴

50. Ultimately, with all embodiments, Butler addresses the shortcomings of the prior art “by providing a relatively compact vacuum cleaner that is long enough to allow typical user to clean elevated stairs without excessive stooping, yet short enough to still provide ergonomic grip and control of the device, and the ability to maneuver in tight spaces, such as enclosed stairwells.”²⁵ As explained below, **it is my opinion that Petitioners and Dr. Giachetti propose modifications of Butler that violate these rules and objectives, and thus are not obvious modifications of Butler.**

51. Numerous statements and considerations in Butler demonstrate that Petitioners’ and Dr. Giachetti’s proposed modifications to Butler would not have been obvious to a POSITA. I summarize these below, which contribute to my opinion that Petitioners and Dr. Giachetti have not shown that claims 1 and 12 of the ’983 Patent are invalid as obvious based on Butler.

²⁴ See Butler (Ex1005) at 19:6–17 (“ . . . that provide the user with hand positions to ergonomically maneuver the device and rotate it into different positions for cleaning horizontal and inclined surfaces”).

²⁵ Butler (Ex1005) at 26:1–5.

a. Butler emphasizes using its vacuum cleaner with two hands

52. Butler teaches that his vacuum is designed for two-handed use. The following excerpts emphasize this teaching:²⁶

- “It is preferred to locate the foregrip 130 at a point along the longitudinal axis 101 that allows the user to comfortably **grasp both grips** and operate the vacuum cleaner 100. In operation, **the user is likely to grasp the rear grip 106 with one hand, and the foregrip 130 with the other hand**, and move the inlet nozzle 104 in a sweeping action across surfaces being cleaned.”²⁷
- “The vacuum cleaner also includes one or more foregrips located on the housing between the rear grip and the air inlet. In various aspects, the foregrips are adapted to [enable a user to] . . . **simultaneously grasp the rear grip and the one or more foregrips** and clean staircase surfaces while remaining substantially upright”²⁸
- “While it is likely that users will grasp the foregrip 130 in numerous different places at various times, it is expected that particular parts of the foregrip 130 will be preferred by many users for a large number of cleaning tasks. For example, it is currently believed that many users will prefer to hold the foregrip 130 generally along the side of the housing 102 for most stair cleaning tasks. This would correspond to

²⁶ All emphases in quotes in this Declaration have been supplied by me unless otherwise noted.

²⁷ Butler (Ex1005) at 14:24–28.

²⁸ Butler (Ex1005) at Abstract.

- about the one-to five-o'clock position on the foregrip 130 (as viewed along the longitudinal axis 101 from the rear grip 106) **for users that place the right hand forward** [and left hand on the rear grip], and about the seven-to eleven-o'clock position on the foregrip 130 **for users that place the right[sic] [left] hand forward** [and right hand on the rear grip]. When the user rotates the device to orient the inlet nozzle 104 to face stair risers, the user is expected to prefer to hold the foregrip 130 about 90 degrees from the original hand grip position, and perhaps as far as the opposite side of the housing. **The user also may wish to hold the foregrip 130 with both hands on both sides of the housing 102** during either horizontal or vertical cleaning, depending on the distance to the surface being cleaned and other factors.”²⁹
- “The foregrip 130 includes various features to enhance the ergonomics and control of the vacuum cleaner 100. For example, **the foregrip 130** shown in Figure 1 has a continuous loop-like shape that surrounds the vacuum cleaner housing 102, which **allows the user to hold the foregrip 130 in virtually any annular location** around the housing 102. . . . **Regardless of which angular position the housing 102 is in, the user can still maintain a firm and comfortable grip on the rear grip 106 and foregrip 130**, and thus on the vacuum cleaner 100 as a whole.”³⁰

²⁹ Butler (Ex1005) at 13:20–14:3.

³⁰ Butler (Ex1005) at 12:3–12.

b. Butler emphasizes imparting forces/torques via a two-grip configuration

53. The following excerpts from Butler support that Butler emphasizes the benefit of being able to impart specific forces and/or torques through its two-grip design:

- “Another advantage of the present invention is that the user can apply a **bending moment force** to the vacuum cleaner housing 102 by **pressing** in opposite directions on the rear grip 106 and foregrip 130. This **bending moment force** can be used to apply **significant pressure** between the inlet nozzle 104 and the surface being cleaned. Such pressure can be helpful to agitate the surface, scrub out deeply-embedded or clinging contaminants and dirt, remove entangled hair and fibers, and so on. In addition, the user can press forward on both grips to **press** the inlet nozzle 104 against the surface being cleaned, but without moving the inlet nozzle 104.”³¹
- “In light of the fact that the grips can be used to generate a **significant bending moment** within the housing 202, this structural portion is preferably constructed to resist such **forces**.”³²
- “The looped foregrip may also be replaced by a grip having a single hand position that is suited to conveniently apply, in conjunction with the rear grip, a **bending moment** on the vacuum cleaner housing.”³³

³¹ Butler (Ex1005) at 12:17–24.

³² Butler (Ex1005) at 16:5–7.

³³ Butler (Ex1005) at 19:12–15.

- “In this embodiment, the housing 502 terminates at the dirt receptacle 514, and therefore the dirt receptacle 514 is constructed as a structural member of the vacuum cleaner 500 that can **convey bending moments and longitudinal loads** from the grips 506, 530 to the inlet nozzle 504.”³⁴

c. Butler emphasizes flexibility/variability in hand positions via its two-grip configuration

54. The following excerpts from Butler support that Butler emphasizes the benefit of having flexibility and variability in hand positions when using its two-grip design:

- “The vacuum cleaner also includes one or more foregrips located on the housing between the rear grip and the air inlet. In various aspects, **the foregrips are adapted to: provide a user with multiple hand positions around the perimeter of the housing; . . .**”³⁵
- “The foregrip is adapted to **provide a user with multiple hand positions** around the perimeter of the housing.”³⁶
- “Preferably, the rear grip 106 is generally circular in shape, and forms a loop that gives the user **flexibility** in selecting an ergonomic position in which to hold the rear grip 106.”³⁷

³⁴ Butler (Ex1005) at 21:9–13.

³⁵ Butler (Ex1005) at Abstract.

³⁶ Butler (Ex1005) at 3:29–4:1.

³⁷ Butler (Ex1005) at 10:19–21.

- “In still other embodiments, the loop-shaped grips may be replaced by any combination of **rear grip and foregrip that provide the user with hand positions to ergonomically maneuver the device and rotate it into different positions** for cleaning horizontal and inclined surfaces.”³⁸
- “The looped foregrip may also be formed as a partial loop **to provide multiple hand positions** around a portion of the vacuum cleaner housing, or separated into multiple separate grips located around the housing.”³⁹
- “While the variations of Figures 3 and 4 do not allow unlimited hand positions on the foregrip, **they still allow greater flexibility and control** than grips on conventional vacuum cleaners.”⁴⁰
- “[T]he rear grip and/or foregrip may be pivotable or otherwise articulated to **provide even greater ergonomic flexibility and control** of the device.”⁴¹
- “. . . one or more foregrips located on the housing between the rear grip and the air inlet, the one or more foregrips being **adapted to provide a user with multiple hand positions** around the perimeter of the housing.”⁴²

³⁸ Butler (Ex1005) at 19:9–12.

³⁹ Butler (Ex1005) at 19:15–17.

⁴⁰ Butler (Ex1005) at 19:30–20:2.

⁴¹ Butler (Ex1005) at 22:26–28.

⁴² Butler (Ex1005) at cl. 1.

d. Butler's two-grip design allows achieving specific configurations during use

55. The following excerpts from Butler support that Butler emphasizes the benefit of its two-grip design being that a user can achieve specific configurations and positions during use:

- “The vacuum cleaner also includes one or more foregrips located on the housing between the rear grip and the air inlet. In various aspects, the foregrips are adapted to [enable a user to] . . . hold and operate the vacuum cleaner when the **housing is rotated about its longitudinal axis at a first angular position and at a second angular position, the first angular position being approximately 90 degrees or more from the second angular position.**”⁴³
- “In still other embodiments, the loop-shaped grips may be replaced by any combination of rear grip and foregrip that provide the user with hand positions to ergonomically maneuver the device and rotate it into **different positions for cleaning horizontal and inclined surfaces.**”⁴⁴

e. Butler teaches away from a single-grip design

56. The following excerpt from Butler supports that Butler teaches away from using a single-grip design:

- In still other cases, upright vacuums having telescoping or collapsible handles have been provided, but **these devices are still difficult to use**

⁴³ Butler (Ex1005) at Abstract.

⁴⁴ Butler (Ex1005) at 19:9–12.

on stairs because they typically have a conventional single-grip design that makes it difficult to address relatively high stairs”⁴⁵

f. Butler teaches locating the two grips with respect to the center of gravity (CG)

57. The following excerpts from Butler support that Butler teaches a specific configuration of its two grips with respect to the CG:

- **“To further add to the ergonomics, it is preferred to locate the center of gravity CG between the foregrip 130 and rear grip 106. Doing so should reduce fatigue by distributing the weight between the user's hands, and improve the ease with which the user can rotate and swing the device.”⁴⁶**
- **“As such, the foregrip 130 should generally surround the device's center of gravity CG, which is likely to be proximal to the longitudinal axis 101. This being the case, as the user rotates the vacuum cleaner 100, the center of gravity CG will remain at generally the same location, causing the general balance of the device to feel the same regardless of its angular orientation. Furthermore, the user will be able to maintain a comfortable hold on the foregrip 130, with his or her hand above or beside the center of gravity CG, regardless of the angular orientation.”⁴⁷**

⁴⁵ Butler (Ex1005) at 25:23–27.

⁴⁶ Butler (Ex1005) at 15:12–15.

⁴⁷ Butler (Ex1005) at 13:3–9.

g. Butler teaches away from the center of gravity (CG) being above the handle

58. The following excerpts from Butler support that Butler teaches away from locating the CG above the handle, as in the '983 Patent:

- “When using these devices [prior art upright and stick vacuums] to clean vertical surfaces, the user was typically required to turn the device over and, if it was then possible, **hold the provided grip with the center of gravity balanced above the user’s hand, typically leading to an unstable situation.**”⁴⁸

h. Butler teaches that the center of gravity (CG) stays in the same place during manipulation

59. The following excerpts from Butler support that Butler emphasizes the benefit of the CG remaining in the same place during use of the vacuum:

- “As such, the fore grip 130 should generally surround the device's center of gravity CG, which is likely to be proximal to the longitudinal axis 101. This being the case, **as the user rotates the vacuum cleaner 100, the center of gravity CG will remain at generally the same location, causing the general balance of the device to feel the same regardless of its angular orientation.** Furthermore, the user will be able to maintain a comfortable hold on the foregrip 130, with his or her hand above or beside the center of gravity CG, regardless of the angular orientation.”⁴⁹

⁴⁸ Butler (Ex1005) at 13:13–16.

⁴⁹ Butler (Ex1005) at 13:3–9.

i. Butler teaches away from handheld vacuum designs

60. The following excerpts from Butler support that Butler teaches away from conventional handheld vacuum designs:

- “**Handheld** vacuums have been used as a substitute for upright, stick and canister vacuums for cleaning stairs and confined spaces, **but such vacuums require the user to stoop, if not kneel, to clean.**”⁵⁰
- “Still other vacuums are provided in compact hand-held configurations that are often very easy to manipulate to clean raised and vertical surfaces. For example U.S. Pat. No. 4,993,108 illustrates a handheld vacuum cleaner with a stair riser cleaning feature that directs the inlet nozzle horizontally without having to rotate the device. **However, even these devices are limited because the handle is located so close to the inlet nozzle, that in many instances the user must kneel or bend to reach the surface being cleaned.**”⁵¹

2. Summary of Rebel

61. German Patent Publication No. 1,608,208, titled “Multipurpose device, in particular handheld vehicle care device,” to Joachim Rebel (“Rebel”) was published on December 23, 1971.⁵² I have been asked to assume that Rebel is prior art

⁵⁰ Butler (Ex1005) at 25:19–21.

⁵¹ Butler (Ex1005) at 3:3–9.

⁵² Rebel (Ex1007) at Cover.

62. Rebel describes a “[m]ultipurpose device” for “handheld vehicle care,” which includes “a motor-driven vacuum cleaner,” “a tool drive, for example for a polishing brush,” and “a water pump connected or connectable to the drive of the vacuum cleaner.”⁵³ Thus, with a single tool, a user can vacuum, spray, and polish a vehicle. The objective of Rebel is to provide all of these features so a vehicle owner “can carry out the various care tasks quickly and without effort and which does not require a great deal of storage space.”⁵⁴

63. As shown below in Figure 1 of Rebel, the “pistol-shaped housing 11” includes a handle 13 and electric motor 14 connected to a suction fan 20.⁵⁵ The vacuum feature of the device functions to “suck in the air and the dust through the suction nozzle 21 and the suction connection 22.”⁵⁶ It uses a “dust bag 23” to achieve separation of dust and air, with the dust bag “detachably attached to the suction connection 22 and can be removed from the housing 11 together with said connection.”⁵⁷

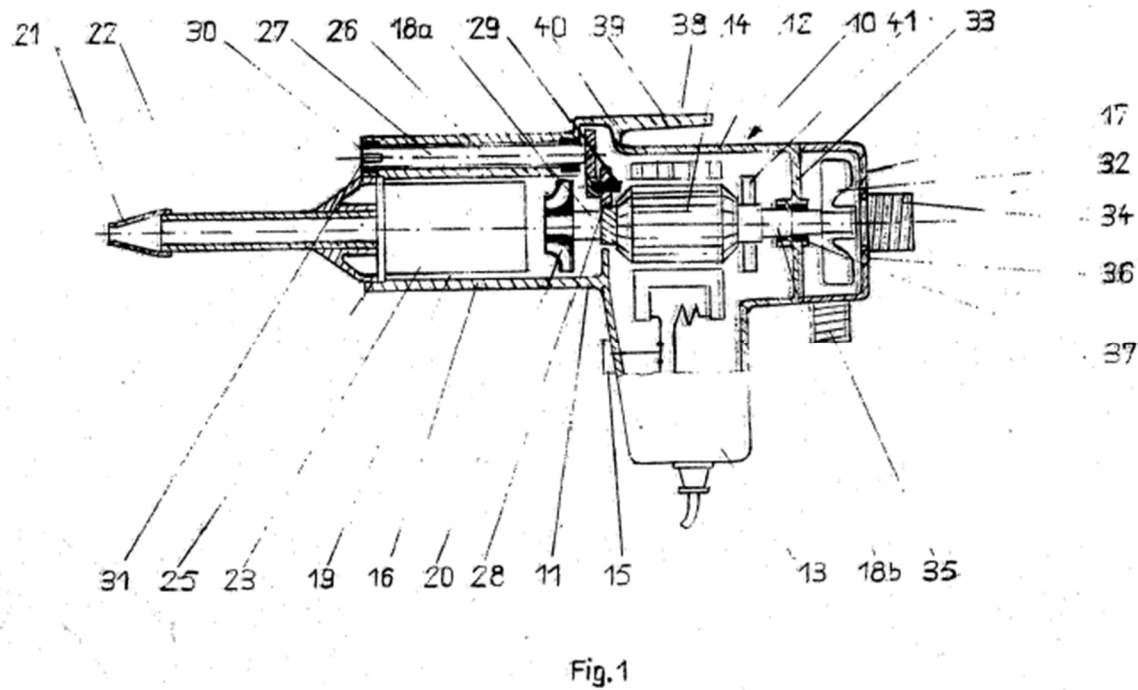
⁵³ Rebel (Ex1007) at 2.

⁵⁴ Rebel (Ex1007) at 2.

⁵⁵ Rebel (Ex1007) at 5, Fig. 1.

⁵⁶ Rebel (Ex1007) at 5.

⁵⁷ Rebel (Ex1007) at 5.



3. Summary of Martelliere

64. French Patent Publication No. 1,094,603, titled “Improved dust vacuums,” to Francois Martelliere (“Martelliere”) was published on May 23, 1955.⁵⁸

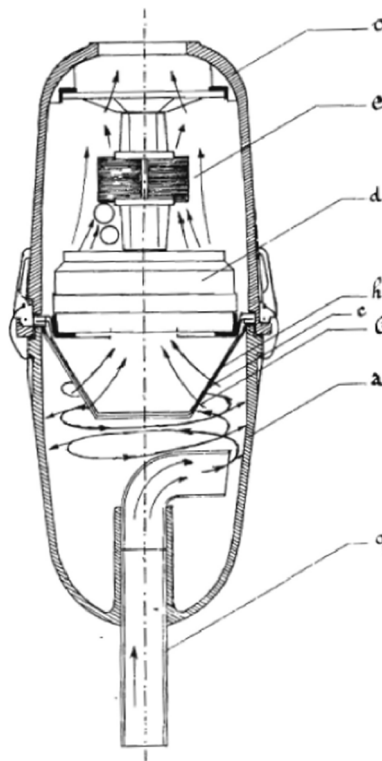
65. Martelliere is a short patent application, with a single figure and only two columns of text. Martelliere relates to a cyclonic separation apparatus for a “broom type vacuum cleaner model.”⁵⁹ Martelliere explains that in some prior art filter separators “the pores of the fabric become blocked, the material accumulates behind the fabric and slows down the aspiration or evacuation of air,” leading to

⁵⁸ Martelliere (Ex1019) at 1.

⁵⁹ Martelliere (Ex1019) at 1.

“poor suction.”⁶⁰ Martelliere thus proposes “[a]pplication of the ‘Whirlwind’ principle and additional filtering using a paper sieve.”⁶¹

66. Martelliere explains that, by application of the “Whirlwind” principle, “arrival of the air sucked tangentially to the interior wall of the transparent container, the materials are deposited in the bottom of the container, after having separated from the air, before it passes through the filter screen, this preventing clogging, hence stable suction.”⁶²



⁶⁰ Martelliere (Ex1019) at 1.

⁶¹ Martelliere (Ex1019) at 1.

⁶² Martelliere (Ex1019) at 1.

67. Martelliere does not describe whether it has a handle.⁶³ A POSITA reading Martelliere would understand that, to the extent it would have a handle, as a “broom type vacuum,” the handle would extend parallel to the axis of the cyclone.

B. Ground 1 – Claims 1 and 12 of the '983 Patent Are Not Obvious Over Butler

68. In Ground 1, Petitioners and Dr. Giachetti contend that claims 1–2, 4–10, 12–15, and 17–21 of the '983 Patent are obvious over Butler alone. I disagree. Claims 1 and 12 are independent, and thus I address those below. Because Butler does not render obvious independent claims 1 and 12, it does not render obvious any of the dependent claims.

69. Broadly, Butler discloses fundamentally different arrangements of handles than that of the '983 Patent, including a different arrangement between the handles and the other components of the vacuum cleaner. Critically, Butler does not disclose in any embodiment the claimed “driving handle” of the '983 Patent.

70. Petitioners incorrectly quote Butler to argue that “Butler’s components, including its dirt receptacle, ‘may be interchangeable with one another to provide the user with various cleaning options.’”⁶⁴ The quote Petitioners include from Butler (16:25–29) says only that “various types of dirt receptacle 214 may be used” with

⁶³ See Martelliere (Ex1019) at 1.

⁶⁴ Petition, 11 (quoting Butler (Ex1005) at 16:25–29).

different embodiments. It does not say that all of “Butler’s components” (e.g., handles, grips, filters, and tools) are “interchangeable.” Similarly, when Butler says that “features described herein are used individually or in various other inventive combinations,”⁶⁵ Butler does not mean that any feature of any embodiment can be used with any other feature of any other embodiment. That is inconsistent with the purpose of Butler, which is to provide an ergonomic vacuum cleaner for cleaning stairwells and other confined spaces.

71. As I explain below, all embodiments of Butler (whether considered individually or collectively) fail to disclose the requirements of the claimed “pistol grip handle” of the ’983 Patent, including one that is “is a driving handle for the surface cleaning apparatus.” Petitioners and Dr. Giachetti also fail to show that the claimed “pistol grip handle” would have been obvious based on Butler alone. To the contrary, Butler teaches away from modifying its grips in the ways suggested by Petitioners and Dr. Giachetti.

1. No Embodiment of Butler Discloses the Claimed “Pistol Grip Handle” Is a “Driving Handle” ([1c.2], [1c.4], [12c.1.ii], [12c.2])

72. Claim 1 of the ’983 Patent discloses specific requirements of the “pistol grip handle” of the “hand vacuum cleaner,” including that it:

⁶⁵ Petition, 11 (quoting Butler (Ex1005) at 43:29–44:3).

- [1c.2] “has a pistol grip portion and an end that is mounted to an outer wall of the hand vacuum cleaner at a location . . . **forward of a rear end of the suction motor,**” and
- [1c.4] “wherein the dirty air inlet of the hand vacuum cleaner is removably drivingly mountable to a downstream end of the rigid air flow conduit whereby when the hand vacuum cleaner is mounted to the downstream end of the rigid air flow conduit, **the pistol grip handle is a driving handle for the surface cleaning apparatus.**”

73. Claim 12 of the '983 Patent contains similar requirements:

- [12c.1.ii] “when the hand vacuum cleaner is mounted to the downstream end of the rigid air flow conduit, **the handle is a driving handle for the surface cleaning apparatus,**” and
- [12c.2] “wherein the pistol grip handle extends generally radially away from an outer wall of the hand vacuum cleaner at a location rearward of the front end and **forward of a rear end of the suction motor.**”

74. For these elements, Petitioners and Dr. Giachetti rely on foregrips 330 (from the Figure 3 embodiment) and 430 (from the Figure 4 embodiment) only.⁶⁶ Petitioners and Dr. Giachetti appear to correctly concede that a looped handle is not a “pistol grip handle,” and thus they do not rely on any embodiments with a looped

⁶⁶ Petition, 24–25; Giachetti Decl. (Ex1002) ¶¶ 128, 152.

handle for the “pistol grip handle” limitations. Petitioners and Dr. Giachetti also do not rely on rear grip 406 of Figure 4 (which is described as “pistol-grip style rear grip”) because it is not mounted to the outer wall of the housing in Butler “at a location . . . forward of a rear end of the suction motor.” As explained below, Petitioners and Dr. Giachetti are incorrect that either foregrips 330 or 430 meet the claimed requirements of the “pistol grip handle,” including that it is a “driving handle.”

a. Foregrips 330 of Figure 3 Are Not a “Pistol Grip Handle”

75. With respect to foregrips 330 of Figure 3, Petitioners and Dr. Giachetti incorrectly assert that they are “pistol grip handles.”⁶⁷ They are not, nor would a POSITA consider them as such. Indeed, Butler does not refer to them as pistol grips, even though he was clearly aware of the term, since he used it when describing the rear grip 406 and foregrips 430.⁶⁸ Pistol-grips are handles that are shaped like a pistol stock. Accordingly, a pistol grip exhibits characteristics of a pistol stock: extending downward from the main body of the device to which it is attached. Generally, pistol grips extend downward vertically from the main body, or both vertically and rearwardly to establish a slight angle with respect to vertical.

⁶⁷ Petition, 19–20; Giachetti Decl. (Ex1002) ¶ 112.

⁶⁸ Butler (Ex1005) at 19:23–24.

76. Stated differently: a POSITA would not consider the straight grips of Figure 3 of Butler to be “pistol grip handles.” Although Butler refers to the hand grips of Figure 4 as “pistol-grip style,” it does not refer to the straight grips as “pistol grips.”⁶⁹ Thus, Butler does not consider those handles to be “pistol grip handles.” A POSITA would recognize that the straight grips of Butler’s Figure 3 extend outward from the body and not down in any way like one would observe with the grip of a pistol.

77. Petitioners and Dr. Giachetti’s incorrect opinions related to foregrips 330 are also conclusory. For example, Petitioners state: “Butler also teaches ‘two separate straight grips 330,’ which a POSA would have understood are pistol-grip handles, at least to the same extent as PO contends infringes.”⁷⁰

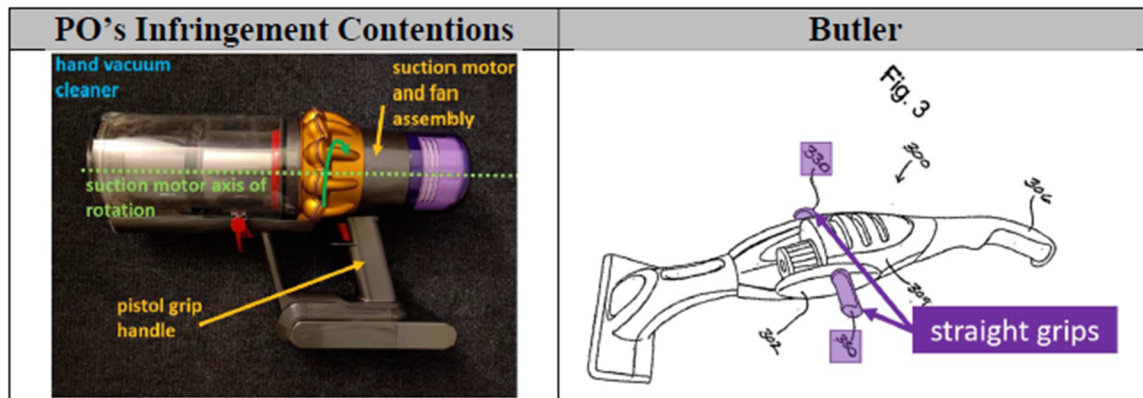
78. Petitioners’ and Dr. Giachetti’s position here seems confused. As shown in the comparison below from the Petition, the accused Dyson products *do* have a pistol grip handle extending downward, below the suction motor and fan assembly. By contrast, the vacuum cleaner of Figure 3 does not. Instead, it has horizontally extending “straight grips 330 that extend generally radially from the vacuum cleaner housing.”⁷¹ Thus, there is no connection between what Patent Owner

⁶⁹ Butler (Ex1005) at 19:18–24.

⁷⁰ Petition, 20; Giachetti Decl. (Ex1002) ¶ 112.

⁷¹ Butler (Ex1005) at 19:18–22.

has accused of infringement and the straight grips of Figure 3 of Butler, even though Petitioners and Dr. Giachetti imply that there is.



79. Thus, the embodiment of Figure 3, or any embodiment with straight grips 330, does not disclose the claimed “pistol grip handle” of claims 1 and 12 of the '983 Patent.

b. Neither Foregrips 330 Nor Foregrips 430 Are a “Driving Handle”

80. In my opinion, Petitioners and Dr. Giachetti have also failed to show that either “foregrips 330” of the embodiment of Figure 3 or the “pistol-grip style foregrips 430” of the embodiment of Figure 4 are “a driving handle” for Butler’s vacuum cleaner, as required by claims 1 and 12 of the '983 Patent.

81. With respect to the “driving handle” requirement, Petitioners’ and Dr. Giachetti’s analysis is sparse. For element [12c.1.ii], Petitioners argue: “When Butler’s hand vacuum cleaner is mounted to the downstream end of the rigid air flow conduit, the handle is a driving handle for the surface cleaning apparatus. Ex1002 ¶127. Butler’s ‘pistol-grip style foregrips 430’ and ‘straight grips 330’ are used to

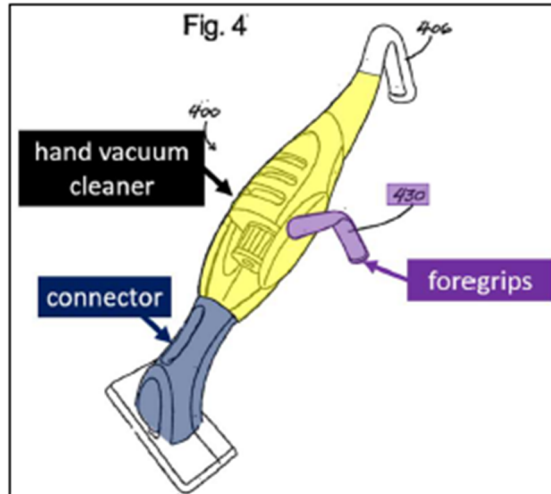
‘ergonomically maneuver the device and rotate it into different positions for cleaning horizontal and inclined surfaces.’”⁷² Similarly, for element [1c.4], Petitioners argue: “Butler’s pistol-grip handles (foregrips 330, 430) are a driving handle for the surface cleaning apparatus because they are used to ‘ergonomically maneuver the device and rotate it into different positions for cleaning horizontal and inclined surface.’”⁷³

82. However, Petitioners and Dr. Giachetti mischaracterize the disclosure in Butler. The portion of Butler quoted by Petitioners refers to the fact that “the loop-shaped grips may be replaced with any combination of rear grip and foregrip that provide the user with hand positions to ergonomically maneuver the device and rotate it into different positions for cleaning horizontal and inclined surfaces.”⁷⁴ In other words, Butler teaches that the *combination* of the rear grip and foregrips allow the maneuverability described. This teaching does not mean that the foregrip alone is a “driving handle.”

⁷² Petition, 24; *see also* Giachetti Decl. (Ex1002) ¶¶ 128, 152.

⁷³ Petition, 35–36. These are the only two places in Ground 1 that Petitioners reference a “driving handle” at all.

⁷⁴ Butler (Ex1005) at 19:6–12.



83. Because the claims refer to a “driving handle,” and not just a “handle” (as other claims in family of the ’983 Patent do⁷⁵), a POSITA would understand that the claim term “driving handle” imbues specific, additional meaning to the claims that are revealed in the specification. In reading the specification, a POSITA would have understood that a “driving handle” is one that could be used to 1) drive (or move) the vacuum for its intended purpose, such as moving it forward and backward across the surface to be cleaned, 2) impart substantial forces to various horizontal and vertical surfaces, and/or 3) manipulate the device’s position and orientation with a high degree of flexibility and control.⁷⁶ These activities are possible with Butler’s

⁷⁵ See U.S. Patent No. 10,219,661 (Ex2005), cl. 1 (“a vacuum cleaner body comprising . . . a handle”).

⁷⁶ See, generally, Section VI.A.1; see also ’983 Patent (Ex1001) at 10:22–27 (“When mounted to upright section 108, a user may grasp handvac 112 to manipulate upright section 108 to steer surface cleaning head 104 across a surface to be cleaned.

device because it facilitates the simultaneous use (*i.e.*, combination) of foregrip and rear grip, not individual use of a single foregrip 330 or 430 as argued by Petitioner and Dr. Giachetti. Said differently, one cannot use the vacuum of Butler as intended with a single foregrip handle, because it is the combination of foregrip and rear grip that enables the sweeping movement, impartation of substantial forces, and highly flexible manipulation and control.

84. Thus, the embodiments of Figures 3 and 4, or any embodiment with foregrips 330 or 430, does not disclose the “driving handle” limitation of claims 1 and 12 of the ’983 Patent.

2. Butler Does Not Render Obvious that the Claimed “Pistol Grip Handle” Is a “Driving Handle” ([1c.2], [1c.4], [12c.1.ii], [12c.2])

85. As explained above, neither the foregrips 330 nor foregrips 430 meet the requirements of the “pistol grip handle” of claims 1 and 12 of the ’983 Patent, including that it be “a driving handle.”⁷⁷ Petitioners and Dr. Giachetti further fail to show that this requirement would have been obvious in view of Butler alone. Indeed, neither Petitioners nor Dr. Giachetti make any argument that the handle(s) of Butler would be modified such that foregrips 330 or 430 would be a “driving handle” of the vacuum cleaner. That is, nowhere do Petitioners or Dr. Giachetti describe

Accordingly, when handvac 112 is mounted to upright section 108, handle 484 is the drive handle of surface cleaning apparatus 100.”), 19:26–29.

⁷⁷ See Section VI.B.1.

modifications to the foregrips 330 or 430 of Butler that would make them a “driving handle.”

86. Although Petitioners and Dr. Giachetti argue that Butler says that some of its embodiments are “interchangeable” and combinable, they never describe or show any embodiments or features that, when combined, meet this claim element. Specifically, Petitioners and Dr. Giachetti do not identify any component in any embodiment of Butler that is a “pistol grip handle” that “mounted to an outer wall of the hand vacuum cleaner at a location . . . forward of a rear end of the suction motor” and is a “driving handle.” Therefore, no combination of Butler’s embodiments would meet this limitation.

87. In Ground 1, Petitioners and Dr. Giachetti propose modifications to the foregrips of Butler, arguing that “a POSA would have found it obvious to improve the maneuverability of Butler’s cleaner by mounting the handle at a location that reduces asymmetrical weight balance caused by heavy components like the motor, thereby increasing ergonomics and reducing strain on the user, which is a stated goal of Butler.”⁷⁸ This argument is not made with respect to the “driving handle” limitation, and Petitioners and Dr. Giachetti never explain how this modification would make the handle of Butler to be a “driving handle.” In any event, I disagree with Petitioners’ and Dr. Giachetti’s proposed modifications to Butler.

⁷⁸ Petition, 33; Giachetti Decl. (Ex1002) ¶ 146.

88. Notably, Petitioners and Dr. Giachetti do not provide any specifics of where the handle in this modified embodiment would be mounted. To the extent Petitioners or Dr. Giachetti are contending that one potential location for a handle in Butler is below the suction motor and fan assembly, I disagree. Butler specifically teaches away from such a handle configuration, as explained below.

89. Butler distinguishes its “stair cleaning vacuum cleaner” from the kinds of hand vacuum cleaner claimed in the ’983 Patent. Butler describes the invention as being different from hand vacuum cleaners in at least four ways that are relevant to the claims of the ’983 Patent:

Configuration: Butler’s invention is comprised of two hand grips. A hand vacuum cleaner, like the one described in the ’983 Patent, has one grip.⁷⁹

Size: Butler’s invention is generally larger than a hand vacuum cleaner.⁸⁰ Butler’s size and configuration is such that it allows a user to “simultaneously grasp the [grips] . . . and clean staircases surfaces while remaining substantially upright.”⁸¹

Adaptability: Butler’s grips are specifically adapted to “provide a user with multiple hand positions around the perimeter of the housing,” such that the

⁷⁹ Butler (Ex1005) at Abstract, 25:23–27, 13:20–14:3, 14:24–28, 12:3–12.

⁸⁰ Butler (Ex1005) at 25:9–26:10.

⁸¹ Butler (Ex1005) at Abstract.

vacuum may be rotated about the longitudinal axis and used in these various orientations.⁸²

Impartation of Forces and Torques: Butler's invention is specifically designed to facilitate imparting forces and torques to a degree not achievable using conventional one-handed hand vacuum cleaners.⁸³

90. Furthermore, Butler's specification spends a lot of time on concerns that do not have anything to do with the one-grip hand vacuum cleaner of the '983 Patent. For example, Butler describes concerns with locating the center of gravity with respect to positioning the handles and maintaining maneuverability.⁸⁴ Butler's concern with locating the center of gravity centrally between two grips and proximal to the axis, so that a foregrip surrounding the longitudinal axis can facilitate angular manipulation of the device about the longitudinal axis without a change in CG location, do not exist with hand vacuum cleaners.⁸⁵ The '983 Patent, simply, locates the handle near the suction motor.

⁸² Butler (Ex1005) at Abstract, 12:3–12.

⁸³ Butler (Ex1005) at 12:17–24, 16:5–7, 19:12–15, 21:9–13.

⁸⁴ Butler (Ex1005) at 13:1–9, 15:12–18.

⁸⁵ Butler (Ex1005) at 13:3–9, 15:12–15.

91. Given these differences, it is my opinion that a POSITA would not view any of Butler's embodiments as a natural starting point for finding a hand vacuum cleaner with the requirements of claims 1 and 12 of the '983 Patent.

92. Furthermore, the proposed modifications to Butler proposed by Petitioners and Dr. Giachetti go against one or more of the specific nine considerations in Butler, including using the vacuum with two hands, imparting forces/torques via a two-grip configuration, achieving flexibility/variability in hand positions, achieving specific configurations and positions during use, not have a single-grip design, locating the two grips relative to the center of gravity, not having the center of gravity above the handle, and maintaining the center of gravity in place during manipulation. I also incorporate by reference my analysis of these considerations in the summary of Butler.⁸⁶

93. Butler directly addresses the issue of how to improve weight balance, reduced strain, and increased maneuverability through its configuration of two handles—the rear grip and the foregrip. A POSITA would not have been motivated to try a solution that is completely different than the one taught in Butler. Indeed, Butler disparages certain modifications of its vacuum cleaner (such as placing a

⁸⁶ See Section V.A.1.

single handle below the center of gravity), stating that it “lead[s] to an unstable situation.”⁸⁷

94. Thus, it is my opinion that a POSITA would not have been motivated to make the modifications to Butler proposed by Petitioners and Dr. Giachetti, and therefore claims 1 and 12 of the '983 Patent are not obvious based on Butler.

C. Ground 2 – Claims 1 and 12 of the '983 Patent Are Not Obvious Over Butler in Combination with Jianan

95. Petitioners and Dr. Giachetti do not contend that the combination of Butler and Jianan renders obvious claims 1 and 12 of the '983 Patent. In this Ground, for the requirements of claim 1 and 12, Petitioners and Dr. Giachetti rely on their analysis from Ground 1.⁸⁸ I therefore incorporate by reference my analysis above of Ground 1 and do not separately address Ground 2.

D. Ground 3 – Claims 1 and 12 of the '983 Patent Are Not Obvious in View of Rebel in Combination with Martelliere

96. In Ground 3, Petitioners and Dr. Giachetti contends that claims 1–2, 4–10, 12–15, and 17–21 of the '983 Patent are obvious over Rebel in combination with Martelliere. I disagree for the reasons explained below.

⁸⁷ Butler (Ex1005) at 13:13–16.

⁸⁸ See, e.g., Petition, 67; Giachetti Decl. (Ex1002) ¶ 241.

97. First, Petitioners and Dr. Giachetti never identify a “surface cleaning head” in either Rebel or Martelliere, as required by claims 1 and 12 of the ’983 Patent.

98. Second, Petitioners and Dr. Giachetti correctly concede that Rebel does not disclose “a cyclone unit comprising a cyclone chamber having a cyclone axis of rotation that extends in a forward/rearward direction,” or that “wherein when the hand vacuum cleaner is positioned with the front end of the hand vacuum cleaner in front of the rear end of the hand vacuum cleaner and the dirty air inlet faces forwardly, the cyclone axis of rotation is generally horizontal.” To fulfill the requirements of these limitations, they argue that “a POSA would have been motivated to combine Martelliere’s cyclonic-separation . . . with Rebel.”⁸⁹ I disagree for the reasons explained below.

1. Rebel and Martelliere Do Not Disclose the Claimed Surface Cleaning Head ([1b], [12b])

99. Elements [1b] and [12b] of the ’983 Patent requires “a surface cleaning head having a front end, a rear end, a dirty air inlet and a surface cleaning head air outlet.” This limitation is not disclosed or rendered obvious by Rebel or Martelliere.

⁸⁹ Giachetti Rpt. (Ex1002) ¶ 702.

100. For this element, Petitioners and Dr. Giachetti point to “suction nozzle 21,”⁹⁰ through which the electric motor “sucks in the air and the dust.”⁹¹ Petitioners and Dr. Giachetti argue that suction nozzle 21 is the claimed surface cleaning head because:⁹²

- 1) it sucks in air and dust;
- 2) the nozzle is three-dimensional and can interact with the surface to be cleaned;
and
- 3) the electric motor sucks in air and dust through the element.

101. I disagree with Petitioners and Dr. Giachetti. A POSITA would understand that the nozzle to which Petitioners and Dr. Giachetti point is not the claimed surface cleaning head. According to Petitioners’ and Dr. Giachetti’s criteria of what constitutes a surface cleaning head, many elements could be a surface cleaning head, provided that air and dirt pass through the element, the element is three-dimensional, and the element can interact with a surface to be cleaned.

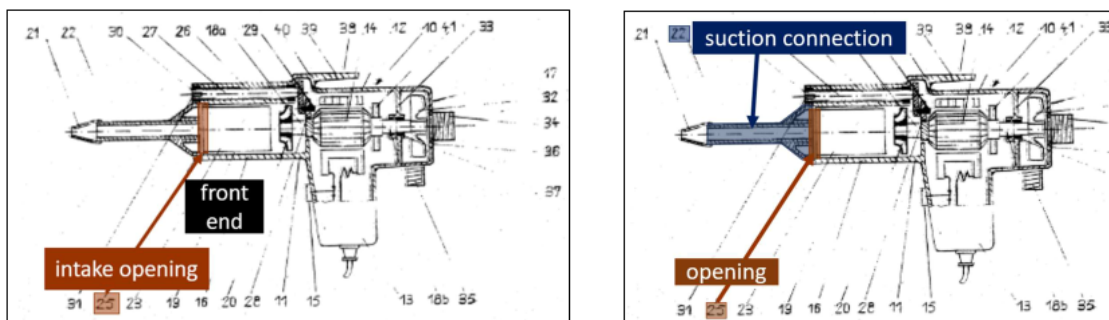
102. Other elements that are clearly not a “surface cleaning head” would qualify under the broad criteria proposed by Petitioners and Dr. Giachetti. For example, one element that meets their criteria is the “intake opening 25,” which

⁹⁰ Petition, 91–92; Giachetti Decl. (Ex1002) ¶ 763.

⁹¹ Petition, 91 (citing Rebel (Ex1007) at 4).

⁹² Petition, 91–92.

Petitioners and Dr. Giachetti assert is the dirty air inlet of claim element [1.a1].⁹³ Since, as per Petitioners and Dr. Giachetti,⁹⁴ suction connection 22 is removable from the intake opening 25, then this opening also meets Dr. Giachetti's criteria for the surface cleaning head: it sucks in air and dust, it is three-dimensional and can interact with the surface to be cleaned, and the electric motor sucks in air and dust through the element.

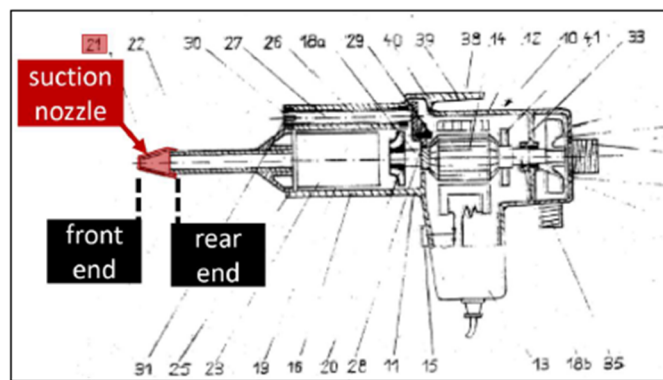


103. Identifying the intake opening thusly demonstrates the absurdity of Petitioners' and Dr. Giachetti's position with respect to the suction nozzle 21. A POSITA clearly recognizes that neither the intake opening 25 nor the suction nozzle 21 are a "surface cleaning head." This is because a POSITA recognizes that a surface cleaning head possesses more attributes than the broad criteria set forth by Petitioners and Dr. Giachetti. Suction nozzle 21 is a small piece that attaches to the end of suction conduit 22, with a very small opening (which appears to be circular)

⁹³ Petition, 83, 102.

⁹⁴ Giachetti Decl. (Ex1002) ¶¶ 786–788.

for sucking in dirt and debris. Suction nozzle 21 is just that—a “nozzle.” But this nozzle is not a “surface cleaning head.” From the disclosure of the ’983 Patent and practical experience, a POSITA understands that a “surface cleaning head” and small nozzle are different in several ways, including at least, with respect to size and shape. For example, a surface cleaning head of this claim would be sufficiently large so that both the “front end” and a “rear end” engage with the surface to be cleaned.⁹⁵ What Petitioners and Dr. Giachetti points to as the “rear end” in suction nozzle 21 is the outer edge of the surface cleaning head air outlet.⁹⁶

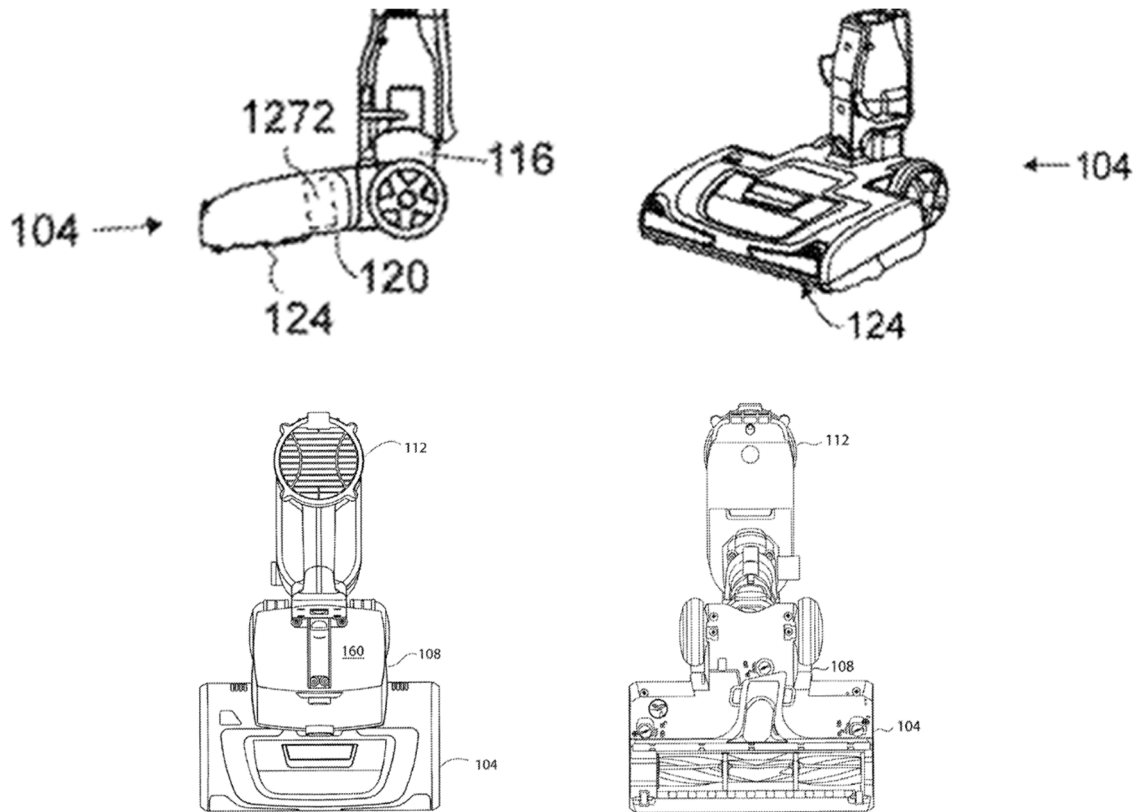


104. Below, for example, are various images from the ’983 Patent showing exemplary “surface cleaning heads” in the embodiments of the Challenged Patent.⁹⁷

⁹⁵ See, e.g., ’983 Patent (Ex1001) at 9:66–10:53, Figs. 1–21.

⁹⁶ Petition, 92.

⁹⁷ ’983 Patent (Ex1001) at Figs. 3 (excerpted), 12a (excerpted), 18.



105. For these reasons, I disagree that Rebel includes the claimed “surface cleaning head.”

106. Petitioners and Dr. Giachetti do not rely on Martelliere with respect to this limitation. I note, nevertheless, that Martelliere does not disclose a surface cleaning head either.⁹⁸ The nozzle on the front of Martelliere is just that—a nozzle. It does not have the attributes of a surface cleaning head, such as a “front end” and a “rear end.”

⁹⁸ Martelliere (Ex1019) at 1, Fig. 1.

2. A POSITA Would Not Have Been Motivated to Modify Rebel to Include the Cyclonic Separation of Martelliere

107. I disagree with Petitioners and Dr. Giachetti that a POSITA would have been motivated to replace Rebel's dust bag separation to use a cyclonic filtration unit as disclosed in Martelliere. In my opinion, a POSITA would not have been motivated to use cyclonic separation in Rebel at all. Rebel discloses a fully formed, working design for a multipurpose device (*i.e.*, a combined vacuum cleaner, polisher, and water sprayer), and there is no need or benefit to modify Rebel as argued by Petitioners and Dr. Giachetti.

a. Rebel and Martelliere are directed at different applications

108. As explained in the summary above, Rebel describes a “[m]ultipurpose device” for “handheld vehicle care,” which includes “a motor-driven vacuum cleaner,” “a tool drive, for example for a polishing brush,” and “a water pump connected or connectable to the drive of the vacuum cleaner.”⁹⁹ The objective of Rebel is to provide all of these features so a vehicle owner “can carry out the various care tasks quickly and without effort and which does not require a great deal of storage space.”¹⁰⁰ By contrast, Martelliere relates to a cyclonic separation apparatus for a “broom type vacuum cleaner model.”¹⁰¹ Because it relates to a broom-type

⁹⁹ Rebel (Ex1007) at 1.

¹⁰⁰ Rebel (Ex1007) at 1.

¹⁰¹ Martelliere (Ex1019) at 1.

vacuum cleaner, a POSITA would understand that Martelliere is much larger in size than Butler.

109. Given these and the other differences between these references discussed herein, a POSITA would not have been motivated to combine Rebel and Martelliere.

b. Rebel's filter-based dust separation technology was effective

110. Rebel describes a fully functional vacuum cleaner with filter-bag-based dust separation technology.¹⁰² Even though at the time of Rebel's invention (in the late 1960's) alternate dust separation technology existed, Rebel does not suggest replacing his filter with a different technology. Indeed, a POSITA at the time of the '983 Patent reading Rebel would understand that Rebel's dust-bag separation system was already highly effective compared with alternate separation methods, including cyclones.¹⁰³

¹⁰² Rebel (Ex1007) at 1, Fig. 1.

¹⁰³ Ex2002 (Comparison of Filter Bag, Cyclonic, and Wet Dust Collection Methods in Vacuum Cleaners, AIHAJ (62) (September/October 2001) at 575, 578, 579, 583 (finding in vacuum technology testing, filter-based separators performed more favorably than cyclonic separators in the areas of pressure drop, efficiency, and particle reentrainment).

c. Accommodating Martelliere's cyclonic separation in Rebel would defeat the objectives of Rebel

111. Another factor unfavorable to adding cyclonic separation to Rebel is related to size. Although patent figures are not necessarily to scale, based on the relative dimensions shown in the figures, a POSITA would understand the vacuum cleaner of Rebel to be relatively small, with its front dirt separation system having a diameter of no more than a two-three inches. Martelliere, by contrast, describes a cyclonic separation system that would seem to be at least several inches in diameter, based on the knowledge that it is incorporated into a broom type vacuum.

112. With awareness of the size disparity, a POSITA would thus understand that Rebel's small dust separation system could not be modified to include Martelliere's large cyclonic separation without increasing the size of Rebel's device. But, this is contrary to the teachings of Rebel, which seeks a small device.¹⁰⁴

d. Miniaturizing Martelliere to accommodate Rebel would diminish the effectiveness of Martelliere

113. A POSITA would also not been motivated to miniaturize the cyclonic separator of Martelliere, such as to fit within the existing housing of Rebel. For example, it was known at the time of '983 Patent that reducing the outside diameter

¹⁰⁴ See Section VI.A.2.

of a cyclone diminishes overall cyclone efficiency.¹⁰⁵ In view of this, and because a POSITA would not expect a cyclonic separation system to improve the effectiveness of Rebel's dust bag filtration, which was already effective, a POSITA would not have been motivated to miniaturize Martelliere's cyclonic separation (thus reducing its effectiveness) to fit in Rebel.

3. Directly Addressing Dr. Giachetti's Reasons Why He Believes a POSITA Would Modify Rebel

114. In his declaration, Dr. Giachetti provides additional details on the purported motivations for modifying Rebel based on Martelliere as included in the Petition.¹⁰⁶ I have reviewed Petitioners' and Dr. Giachetti's arguments and I disagree. Broadly, the motivations proposed are areas that Rebel has already solved and that do not need improvement. I address these purported motivations below.

¹⁰⁵ Ex2003 (Linden, *Investigations into Cyclone Dust Collectors*, Proceedings of the Institution of Mechanical Engineers (1949)) at 234–235 (“Enlarging the cyclone diameter D also increases the efficiency”); Ex2004 (Kim et al., *Experimental Study of Particle Collection by Small Cyclones*, Aerosol Science and Technology (1990)) at 1007–1008 (“[T]he particle collection efficiency for a cyclone having a larger body diameter is higher than that for a smaller cyclone.”), 1013–1014.

¹⁰⁶ Petition, 78–81.

a. Giachetti: Cyclonic filtration is better than dust-bag filtration

115. Dr. Giachetti identifies purported benefits of cyclonic filtration over dust-bag filtration.¹⁰⁷ I disagree that these purported benefits are applicable here.

116. The first purported benefit is that cyclonic filtration overcomes disadvantages of “dust bag” filters. Once such disadvantage being that they are costly because they require replacing.¹⁰⁸ Although Rebel discloses using a bag for filtering, not all filter-based separation mechanisms require a replaceable bag. Nothing in Rebel teaches against using a different form of non-cyclonic filtering that does not require a bag, such as a system in which the user empties, rinses, or otherwise cleans a reusable filter periodically. A POSITA would understand that a vacuum cleaner the size of Rebel’s would not necessarily require a disposable filter bag. For example, a filter could be used that retains debris in the front portion that can be dumped when suction nozzle 21 is removed.¹⁰⁹ Thus, any benefits of not using a filter bag could be achieved without fundamentally changing the separation system.

¹⁰⁷ Giachetti Decl. (Ex1002) ¶¶ 52, 263–269.

¹⁰⁸ Giachetti Decl. (Ex1002) ¶¶ 52, 269.

¹⁰⁹ Rebel (Ex1007) at 5.

117. The second purported benefit is that cyclonic separation achieves “stable suction” and prevents clogging.¹¹⁰ I disagree that this statement is universally true and universally a motivation to move to cyclonic separation. Suction loss is a function of many factors, and not all cyclonic separators necessarily have less suction loss than filter-based separators. In fact, a POSITA would have been aware that in some vacuums, greater suction loss occurs in cyclonic separators than bag filters.¹¹¹ For example, a POSITA would have understood that there could be substantial back pressure (leading to suction loss) across a single small cyclone (as proposed by Petitioners and Dr. Giachetti).

118. The third purported benefit is that, by using a transparent cyclonic chamber, “the user is able, when stopped, to see where the filling of the container is” and “can therefore better judge when it must be emptied.”¹¹² This is not a benefit unique to cyclonic separators. Butler, for example, discloses non-cyclonic embodiments with a clear housing to give a visual indication of how full the container is.¹¹³ Thus, a POSITA could modify Rebel to include a clear housing without implementing cyclonic separation.

¹¹⁰ Giachetti Decl. (Ex1002) ¶ 264.

¹¹¹ Ex2002 (Comparison of Filter Bag, Cyclonic, and Wet Dust Collection Methods in Vacuum Cleaners, AIHAJ (62) (September/October 2001)) at 575, 578, 579, 583.

¹¹² Giachetti Decl. (Ex1002) ¶ 264.

¹¹³ Butler (Ex1005) at 15:19–18:2, Figs. 2A–2C.

b. Giachetti: It would have been obvious to try modifying Rebel

119. Dr. Giachetti argues: “In my opinion, a POSA would have also found it obvious to at least try this combination. There were a finite number of identified dust-separation solutions, including dust bags (as Rebel teaches) and cyclonic separators with a filter (as Martelliere teaches), and in my opinion a POSA would have been motivated to use cyclonic separation with a filter as taught by Martelliere to achieve its known benefits.”¹¹⁴

120. However, just because something was known, and could theoretically have been attempted, does not mean that it would have been obvious to try to do so. In this case, for example, there would have been no reason for a POSITA to modify Rebel’s filter, since, as explained above, it was effective.

121. If the benefits of cyclonic separators were so well known and indisputable as Dr. Giachetti argues, then one would expect all vacuums to be cyclonic. That is not the case. Indeed, there have been vacuum cleaners, both before and after Rebel, that use filter separators and clear housings to view the collected debris. For example, Butler discloses non-cyclonic embodiments that have the benefit of a clear housing to know when it needs to be emptied.¹¹⁵

¹¹⁴ Giachetti Decl. (Ex1002) ¶ 268.

¹¹⁵ Butler (Ex1005) at Figs. 2A, 2B, 2C.

122. Thus, a POSITA would understand that the benefits alleged by Dr. Giachetti for cyclonic separators are not unique to cyclonic separators. As such, a POSITA would have no reason to modify the separation system of Rebel to seek those benefits.

c. Giachetti: Modifying Rebel involves a simple substitution

123. Dr. Giachetti argues: “In my opinion, a POSA would have been motivated to make this simple substitution of one known dust-separating element (dust bag chamber) for another (cyclone chamber with a filter) to obtain predictable results (dust separation).”¹¹⁶

124. I disagree for the reasons explained above. The results are not predictable at all, given that Martelliere’s cyclonic separation could not be implemented in Rebel without either 1) increasing the size and weight of the Rebel vacuum cleaner, which is contrary to the teachings of Rebel, or 2) decreasing the size of Martelliere’s cyclone, which would diminish the effectiveness of the cyclone separation system.

d. Giachetti: The prosecution history of the ’983 Patent supports the proposed modification

125. Dr. Giachetti argues: “[D]uring prosecution of the ’983 Patent, the Examiner found (and the Applicant did not dispute) that it would have been obvious

¹¹⁶ Giachetti Decl. (Ex1002) ¶ 266.

to substitute cyclonic-separation units for non-cyclonic separation units.”¹¹⁷

Dr. Giachetti’s argument appears to be, broadly, that during prosecution, the examiner said that:

- “[I]t would have been obvious to one skilled in the art at the time of the invention to substitute the cyclone unit in Conrad for the separation assembly in the hand vacuum cleaner in Mori et al. since the cyclone unit in Conrad is used for the same purpose of separating dust particles from air as the separation assembly in Mori et al.”

And, according to Dr. Giachetti, the applicant did not dispute this.¹¹⁸

126. Dr. Giachetti misreads the prosecution history. At the end of the amendment in which the applicant added the handle limitations to claims 1 and 12, the applicant included the following disclaimer to make it clear that it did not agree with the statements made by the examiner:

- “Although the present communication may include alterations to the application or claims, or characterizations of claim scope or referenced art, Applicant is not conceding in this application that previously pending claims are not patentable over the cited references. Rather, any alterations or characterizations are being made to facilitate expeditious prosecution of this application. . . . Accordingly, reviewers of this or any parent, child or related prosecution history shall not reasonably

¹¹⁷ Giachetti Decl. (Ex1002) ¶ 269.

¹¹⁸ Giachetti Decl. (Ex1002) ¶ 269.

infer that Applicant has made any disclaimers or disavowals of any subject matter supported by the present application.”¹¹⁹

127. Thus, a POSITA reviewing the prosecution history would *not* conclude that the applicant did not dispute that substituting a cyclonic separator for a non-cyclonic separator would have been obvious. In any event, the argument made by the examiner during prosecution was specific to the references of Conrad and Mori, and for the reasons explained above a POSITA would *not* have been motivated to modify the separation system of Rebel.

128. For at least these reasons, it is my opinion that a POSITA would not have been motivated to modify Rebel as argued by Petitioners and Dr. Giachetti. It is therefore my opinion that Petitioners and Dr. Giachetti have not shown that Rebel in combination with Martelliere renders obvious claims 1 and 12 of the '983 Patent.

E. Ground 4 – Claims 1 and 12 of the '983 Patent Are Not Obvious Over Rebel in Combination with Martelliere and Jianan

129. Petitioners and Dr. Giachetti do not contend that the combination of Rebel, Martelliere, and Jianan renders obvious claims 1 and 12 of the '983 Patent. In this Ground, for the requirements of claim 1 and 12, Petitioners and Dr. Giachetti rely on their analysis from Ground 3.¹²⁰ I therefore incorporate by reference my analysis above of Ground 3 and do not separately address Ground 4.

¹¹⁹ '983 File History (Ex1004) at 280.

¹²⁰ See, e.g., Petition, 125; Giachetti Decl. (Ex1002) ¶ 406.

VII. CONCLUSION

130. I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

131. I also 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 and that willful false statements and the like so made could jeopardize the validity of the patent at issue in this proceeding.

Executed this 12th day of December, 2024.



Dr. Khalid Sorensen

QUALIFICATION SUMMARY

HIGHLIGHTS

- Highly accomplished technology leader in fields of mechatronics, motion control, adaptive manufacturing, machine vision, and human-machine interaction.
- Founder and CTO of successful technology company - acquired 5 years after inception by global leader in automation.
- CTO at world-class supplier of sophisticated robotics, control, advanced manufacturing, and nuclear handling solutions with gross annual sales of approx. \$30M.
- Associate Professor at the Georgia Institute of Technology, Woodruff School of Mechanical Engineering.
- Chief architect of world-class mechatronic technologies, motion-control algorithms, and products for advanced robotics and automation.
- Directed development and implementation of hundreds of complex, multi-disciplinary mechatronic systems for high-profile industry leaders such as Toyota, Ford, Alcoa, Caterpillar, Boeing, NuScale, and many others, as well as high-profile facilities such as Fukushima and Chernobyl.

INDUSTRY

Dr. Khalid Sorensen has over 20 years of experience developing and deploying cutting-edge mechatronic, motion control, and automation solutions. He is the founder of a technology company where he invented and was the chief architect of Expertoperator™, Safemove™, Automove™, and Cranevision™ – technology known within the primary metals, automotive, and heavy-equipment sectors for enhancing crane safety, productivity, and ease-of-use. Sorensen also developed state-of-the-art, on-line, time-optimal trajectory synthesis software for Cartesian machines. These industry-recognized technologies were key drivers in the acquisition of his company 5 years after inception by a global leader in automation.

Dr. Sorensen also served as CTO at PaR Systems, a world-class supplier of large-scale robotic automation, control, advanced manufacturing, and nuclear-handling solutions. Responsibilities included: technical oversight of critical projects; identifying and mitigating technical risk areas; leading in the creation of new and cutting-edge control, automation, and robotics technologies; directing R&D efforts; managing and protecting IP portfolio; disseminating and facilitating best-practice engineering methodologies; identifying and adopting emerging technologies for advancing company's technical capabilities; and identifying and executing strategic partnerships.

In 2020, Dr. Sorensen founded Finity Engineering (FE), and presently serves as CTO. FE provides design, analysis, consulting, and litigation support services in the areas of robotics, automation, mechatronics.

ACADEMIA

Dr. Sorensen is an Adjunct Associate Professor at the Georgia Institute of Technology. He teaches on various engineering topics including Dynamics, Advanced Motion Control, Vibrations, Mechatronics, The Design Process, Product Development, Engineering Best Practices, Intellectual Property, Product Liability, and others. In addition to Georgia Tech, Sorensen has given invited talks in these areas at premiere institutions globally including MIT, Kumoh National University of Technology, the Korea Atomic Energy Research Institute, Hyung Hee University, and Huazhong University of Science & Technology. Sorensen is a named inventor on multiple patents, and has published dozens of refereed journal and conference articles pertaining to advanced motion control and human factors. Dr. Sorensen is a former NSF STEP Fellow, USAA National Collegiate Engineer, and ARCS fellowship recipient.

LITIGATION SUPPORT

Dr. Sorensen has been recognized as an expert in numerous product liability and IP disputes – by Federal courts, as well as by the ITC, USPTO, PTAB, and US Customs and Border Protection. Areas of expertise in which he has provided litigation support include: automation, dynamics and controls, kinematics, machine vision, mechatronics, photogrammetry, robotics, sensors, Segways and Hoverboards, tire mechanics, traction control, wheel slip, vibrations, and warnings.

EDUCATION**Doctor of Philosophy – Mechanical Engineering** 2008*Georgia Institute of Technology, Atlanta, GA.*

- Concentration: System Dynamics and Controls
- Thesis: Operational Performance Enhancement of Human Operated Flexible Systems
- Adviser: Dr. William Singhose
- GPA: 4.0

Master of Science – Mechanical Engineering 2005*Georgia Institute of Technology, Atlanta, GA.*

- Thesis: A Combined Feedback and Command Shaping Controller for Improving Positioning and Reducing Cable Sway in Cranes
- Adviser: Dr. William Singhose
- GPA: 4.0

Bachelor of Science – Mechanical Engineering 2002*Walla Walla University, College Place, WA.*

- Summa Cum Laude
- Senior Project: Design of a Low Head-Loss Vane Pump
- GPA: 3.94

Associates of Science – Engineering 1999*Southern Adventist University, Collegedale, TN.*

- Magna Cum Laude
- GPA: 3.9

CONSULTING & EXPERT WITNESS ACTIVITIES

EXPERT WITNESS CASE STATISTICS

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EXPERT WITNESS CASES & CONSULTING

Bastian v. Attabotics Apr 2024 – Present

Firm: Quarles & Brady LLP
 Type: Contract
 Number: 1:23-cv-00198 (Sothorn District of Indiana)
 Work Product: Consulting, Functional Requirements, Elements, Deficiencies Analysis.
 Roll: Mechatronics Expert.

Schouten v. Gea Sep 2023 – Present

Firm: Stueve Siegel Hanson LLP
 Type: Contract
 Number: 23-cv-00142 (Northern District of Texas)
 Work Product: Site visits & Consulting.
 Roll: Mechatronics Expert.

Neil Jones v. Factory Technologies Jun 2023 – Present

Firm: Farbstein & Blackman
 Type: Contract
 Number: 5:21-cv-09885 (Northern District of California)
 Work Product: Consulting.
 Roll: Industrial Material Handling and Mechatronics Expert.

Robogistics v. Siemens Feb 2023 – Aug 2023

Firm: Reed Smith
 Type: Contract
 Number: 1:22-cv-00474 (Eastern District of Texas)
 Work Product: Consulting.
 Roll: Industrial Material Handling and Mechatronics Expert.

BPS v. Blue Phoenix Inashco Mar 2023 – May 2023

Firm: Allen & Overy
 Type: Contract
 Number: 1:21-CV-00662 (Northern District of Ohio Eastern Division)
 Work Product: Expert Report.
 Roll: Opined on Issues of Trade Secret Misappropriation Related to PLC Process Control of Incinerator Ash Processing Technology.

Pattama Ang v. Harbor Industrial Services Jul 2022 – Present

Firm: Law Offices of Preston Easley APC
 Type: Product Liability
 Number: 22STCV17151 (Superior Court of California, Los Angeles County)
 Work Product: Consulting.
 Roll: Opined on Issues of Industrial Crane Safety, and Anti-Collision Technology.

Triple S Farm v. DeLaval Jun 2022 – Present

Firm: Stueve Siegel Hanson LLP
 Type: Contract
 Number: 4:22-cv-00309 (Western District of Missouri)
 Work Product: Site visits & Consulting.
 Roll: Mechatronics Expert.

Kruger v. Lely Jun 2022 – Sep 2022

Firm: Stueve Siegel Hanson LLP
 Type: Contract
 Number: 0:20-cv-00629 (District of Minnesota)
 Work Product: Site visits & Consulting.
 Roll: Mechatronics Expert.

Bissell v. Tineco Mar 2022 – Dec 2022

Firm: Quinn Emanuel Urquhart & Sullivan LLP
 Type: Patent / IPR
 Number: 337-TA-1304
 Work Product: Document Review & Consulting; Infringement & Validity Reports; Construction Declaration; Deposition & Trial Testimony.
 Roll: Opined on Mechatronics Issues Related to Wet/Dry Vacuum Technology, Infringement, Validity, DI, Secondary Considerations.

Sumner v. Manitowoc Mar 2022 – Dec 2022

Firm: Saltz Mongeluzzi & Bendesky PC
 Type: Product Liability
 Number: TBD
 Work Product: Data Logger Analysis Report.
 Roll: Analysis of “Black Box” Data.

Ocado v. Autostore Apr 2022 – Jul 2023

Firm: Kirkland & Ellis LLP
 Type: Patent
 Number: 1:21-cv-00041
 Work Product: Document Review & Consulting.
 Roll: Opined on Issues Related to Automated Storage & Retrieval Systems, Noninfringement and invalidity.

Fisher v. ABB Dec 2021– Oct 2022

Firm: McKool Smith
 Type: Patent
 Number: 4:18-cv-00178
 Work Product: Document Review & Consulting.
 Roll: Opined on Issues of Industrial Automation & Controls Hardware & Software.

Opex v. HC Robotics Dec 2021 – Dec 2022

Firm: Desmarais LLP
 Type: Patent / IPR
 Number: 337-TA-1293
 Work Product: Document Review & Consulting. Infringement Report; Deposition & Trial Testimony.
 Roll: Opined on Automated Storage & Retrieval Systems, Infringement, and DI.

iRobot v. SharkNinja Apr 2021 – Jan 2021

Firm: Gibson, Dunn & Crutcher LLP

Type: Patent / IPR

Number: 337-TA-1252

Work Product: Expert Report, Rebuttal Report, Deposition, Trial Testimony.

Roll: Opined on Mechatronics Issues Related to Autonomous Robot Vacuums, Validity, Infringement, and DI.

Tucker v. Segway Mar 2021 – May 2021

Firm: Dordick Law Corporation

Type: Product Liability

Number: NA

Work Product: Segway Inspection.

Roll: Opined on Segway, Controls, Mechatronics, and Warnings Issues.

Bishop v. DeLaval Nov 2020 – Nov 2021

Firm: Stueve Siegel Hanson LLP

Type: Contract

Number: 5:19-cv-06129 (District Court, Western District of Missouri)

Work Product: Expert Report (Functional Requirements Analysis, and Product Defects), Deposition.

Roll: Opined on Issues Related to the Mechatronics and Functionality of Automated Milking Systems.

Autostore v. Ocado Nov 2020 – Dec 2020

Firm: Kirkland & Ellis LLP

Type: Patent Litigation / ITC

Number: 337-TA-1228

Work Product: Consulting.

Roll: Opined on Issues Related to an Automated Storage & Retrieval System.

Empirical Foods v. Primus Builders Jan 2020 – Feb 2022

Firm: Benesch, Friedlander, Coplan & Aronoff LLP

Type: Contract

Number: 8:19-cv-00457 (District Court of Nebraska)

Work Product: Expert Report, Consulting, Testing Protocols and Oversight.

Roll: Opined on Issues Related to the Functionality of an Automated Storage & Retrieval System and the Standards/Best Practices of the Engineering Process.

Provisur v. Weber Jun 2019 – Dec 2019

Firm: Jenner & Block LLP

Type: Patent

Number: 5:19-cv-6021 (District Court, Western District of Missouri St. Joseph Division)

Work Product: Analysis and Consulting.

Roll: Opined on Mechatronics Issues.

Usewick v. Smugglers' Notch May 2019 – Oct 2019

Firm: Clark, Werner & Flynn, PC

Type: Product Liability

Number: 5:18-cv-120 (District Court, District of Vermont)

Work Product: Expert Report (Failure Mode, Hazard, Training, Warning Analyses), Deposition.

Roll: Opined on Segway, Controls, Mechatronics, and Warnings Issues.

Zirlott Estate v. Discountramps Feb 2019

Firm: Tobias, McCormick & Comer, LLC
 Type: Product Liability
 Number: 1:19-cv-00218 (District Court, Alabama Southern District)
 Work Product: Dynamic Analysis & Simulation of Incident.
 Roll: Opined on Dynamics of Falling Person/Ladder.

Wirtgen v. Caterpillar Jan 2019 – Jun 2019

Firm: Finnegan, Henderson, Farabow, Garrett & Dunner, LLP
 Type: Patent / IPR
 Number: IPR2018-01200
 Work Product: Two Declarations on Validity and Claim Amendments, Two Depositions.
 Roll: Opined on Controls and Mechatronics Issues and Validity.

Pederson v. Ninebot Dec 2018 – Feb 2019

Firm: The Cavanagh Law Firm, PA
 Type: Product Liability
 Number: 2:2018-cv-00918 (District Court, District of Arizona)
 Work Product: Discovery Recommendations, Assessment of Design/Manufacture/Warning Adequacy.
 Roll: Opined on Segway, Controls, Mechatronics, and Warnings Issues.

George v. Segway Sep 2018 – Nov 2018

Firm: Mathews Law Firm, PC
 Type: Product Liability
 Number: 13AF-CC00393 (Circuit Court of Taney County, Missouri)
 Work Product: Expert Report (Failure Mode Analysis, Hazards Analysis, Warning Analysis).
 Roll: Opined on Segway, Controls, Mechatronics, and Warnings Issues.

Hyosung v. Diebold Aug 2017 – Sep 2017

Firm: Alston & Bird, LLP
 Type: Patent / Redesign in Connection with ITC Exclusion Order
 Number: 337-TA-989
 Work Product: Declaration, Software Analysis Overview Drawings, ATM Testing Report.
 Roll: Physical Testing and Software Review of ATM to Validate Redesign Requirements.

Mary Ellen Frese v. City Segway Tours Apr 2017

Firm: Trombly & Singer PLLC
 Type: Product Liability
 Number: 16-2373 (District Court, District of Columbia)
 Work Product: Segway Crash Site Survey.
 Roll: Survey of Segway crash site.

Segway v. Swagway Dec 2016 – Apr 2017

Firm: Mei & Mark, LLP
 Type: Patent Litigation / ITC
 Number: 337-TA-1007/1021 Consolidated
 Work Product: Expert Report, Deposition, Trial Testimony.
 Roll: Source Code Analysis, Opined on Dynamics & Mechatronics Issues, Non-Infringement/DI.

Lawson v. Segway Nov 2016 – Oct 2017

Firm: Lathrop & Gage, LLP
 Type: Product Liability
 Number: 2015CV31355 (District Court, Boulder County, Colorado)
 Work Product: Expert Report, Rebuttal Report I, Rebuttal Report II, Deposition.
 Roll: Source Code Analysis, Opined on Dynamics & Mechatronics Issues, Traction/Motor Control and Relationship to Machine Stability.

Hyosung v. Diebold Oct 2016 – Jan 2017

Firm: Alston & Bird, LLP
 Type: Patent Litigation / Patent Office Covered Business Method
 Number: CBM2016-00034
 Work Product: Declaration, Deposition.
 Roll: Opined on Machine Vision & Imaging Technologies and Validity.

Hyosung v. Diebold Jul 2016 – Nov 2016

Firm: Alston & Bird, LLP
 Type: Patent Litigation / ITC
 Number: 337-TA-989
 Work Product: Expert Report, Deposition, Trial Testimony.
 Roll: Source Code Analysis, Opined on Non-Infringement, and Various Sensors.

Williams v. Manitowoc May 2015 – Oct 2016

Firm: Tobias, McCormick & Comer, LLC
 Type: Product Liability
 Number: 1:14-CV-383 HSO-JCG (US Court of Appeals for the Fifth Circuit)
 Work Product: Expert Report, Rebuttal Report, Two Depositions, Trial Testimony.
 Roll: Photogrammetric Analysis of Crane Collapse Video, Opined on Cable Angle Warning System Viability for Mobile Boom Cranes, Dynamic Analysis Critique.

Lee v. Thyssenkrupp Steel Jun 2015 – May 2016

Firm: Diamond Fuquay LLC
 Type: Product Liability
 Number: CV-2013-902531.00 (Circuit Court of Mobile County Alabama)
 Work Product: Deposition.
 Roll: Reviewed Depositions & Crane Drawings/Manuals, Consulted on Crane Maintenance Best Practices & Operation, Synthesized Failure Mode Hypothesis.

Manitowoc v. Sany America Oct 2013 – Feb 2014

Firm: Morris, Manning, & Martin
 Type: Patent Litigation / ITC
 Number: 337-TA-887
 Work Product: Expert Report.
 Roll: Reviewed Patents & Depositions, Functional Analysis of Crane Software for Patent/Trade Secret Infringement.

INDUSTRY ACTIVITIES

FOUNDER & CHIEF TECHNOLOGY OFFICER

Finity Engineering, Walla Walla, WA 2020 – Present

Duties & Responsibilities:

- Lead teams of highly accomplished experts with substantial industrial automation, mechatronic, robotics, and consumer-product experience, together with leading researchers at top engineering universities to provide design, analysis, consulting, and litigation support services.
- Respond to strategic RFPs and RFIs.

Key Highlights:

Oversight and execution of fundamental and applied research efforts within the fields of dynamics, vibration, and controls with application to haptic motors. These efforts resulted in the development of novel haptic actuators, and new characterization, modeling, and control techniques with broad application to consumer mobile devices and wearables. Development and extensive use of forensic analysis software for industrial and construction crane accidents. Design methodology analyses for high-value mechatronic systems including a \$30M warehouse automation system, and automatic milking machines at issue in a class action resulting in a \$55M settlement. Design support for the largest NOG-1 crane manipulator in the world with ultra-precise position/orientation capabilities.

CHIEF TECHNOLOGY OFFICER & ENGINEERING FELLOW

PaR Systems, Shoreview, MN 2013 – 2020

Duties & Responsibilities:

- Position PaR as a technical leader by facilitating the development, testing, and implementation of next-generation motion control technology. Direct R&D efforts and budgets.
- Identify and adopt emerging technologies important to advancing PaR's technical capabilities.
- Identify and execute strategic technology partnerships.
- Oversee projects with critical technical content or risk. Identify and mitigate areas of technical risk.
- Strengthen PaR's offerings by implementing new product features and capabilities, evaluating products critically and facilitating improvements.
- Disseminate and facilitate the use of best-practice engineering methodologies to deliver best-in-class solutions.
- Respond to strategic RFPs and RFIs.
- Facilitate identification, prosecution, and management of intellectual property.

Key Highlights:

Developed first-in-class motion technology presently deployed on over 500 cranes and industrial robots throughout the world in automotive, primary metals, heavy equipment, aerospace, print, nuclear, and other industries. Directed development of largest NOG-1 crane manipulator in the world with ultra-precise position/orientation capabilities. Oversight and execution of critical R&D projects including: novel remote manipulator for nuclear environments, morphing algorithms for adaptive manufacturing, pendant-embedded anti-sway product, 2D and 3D custom machine vision systems for robust localization and real-time tracking in unstructured environments. Developed strategic partnerships with industry leaders for co-development of novel motion products. Developed and implemented guidelines for managing and protecting IP.

CO-FOUNDER & CHIEF TECHNOLOGY OFFICER

CAMotion Cranes, Atlanta, GA 2008 – 2013

Duties & Responsibilities:

- Development of next-generation motion control algorithms.
- Business development and development of strategic partnerships.
- Oversee and develop advanced control techniques for the motion and user performance of industrial material-handling machines.
- Product development.

- Implement, test, and debug control strategies on industrial hardware platforms.
- Conduct control theory learning sessions for company personnel.

Key Highlights:

Chief architect and developer of world-class motion control technologies now widely used and recognized throughout select industries: Expertoperator™, Safemove™, Automove™, and Cranevision™. Developed state-of-the art trajectory synthesis method that simultaneously satisfies geometric, kinematic, oscillatory, and time-optimality constraints. These technologies were of paramount importance in the 2013 acquisition of CAMotion Cranes by PaR Systems. These technologies also facilitated the development of two disruptive technology products: the CAMotion Log Depalletizer (LDP) and Expertoperator-plus (EOP) crane control system.

CRANE CONTROL SPECIALIST

Georgia Tech Sponsored Project at Logan Aluminum, Russellville, KY. 2007 – 2008

Project: Crane Manipulation System Development and Installation.

Duties & Responsibilities:

- Integrate state-of-the-art technologies in machine vision, range sensing, oscillation suppression, positioning capabilities, and interface design into a unified crane manipulation system.
- Implement motion algorithms on a PLC-based automation platform.
- Develop interface software for communication between system components.
- Install system on 30-ton and 35-ton industrial bridge cranes.

Key Highlights:

Two industrial cranes at Logan Aluminum have been equipped with the developed crane manipulation system (CMS). This technology permits operators to drive the cranes in a swing-free manner, and simplifies precise positioning tasks. Beneficial attributes of the CMS-enabled cranes include increased safety and efficiency. Through facilitating the development of the CMS from concept, to design, to product, and finally to installation, I have gained a working competence in both control theory and automation mechatronics.

PROJECT ENGINEER

CH2M-Hill Hanford Group, Richland, WA..... 2003

Project: Design of a Waste Packaging System for Hanford Transuranic Sludge Waste.

Duties & Responsibilities:

- Collaborate with Pacific Northwest National Laboratory to obtain rheological and nuclear properties of transuranic waste.
- Develop dynamic model of transuranic slurry flow.
- Determine anticipated cesium concentration in residual waste streams.
- Determine critical transport velocities and corresponding waste dilution factors to insure fully suspended and transportable flow.

Key Highlights:

My efforts were directed at developing nuclear cleanup technologies for Hanford waste. This work was motivated by the need to accelerate tank waste cleanup for the purpose of quickly reducing environmental and human risk. My results were instrumental in producing two Hanford documents: The *Procurement Specification for CH-TRU Packaging Unit and Support Equipment*, and the *Interface Control Document for the TRU Waste Retrieval Systems and the Contact Handling Waste Packaging Subsystem*. This work represents my first involvement with industry after obtaining my undergraduate degree in mechanical engineering. It provided me with a level of competence at using fundamental engineering knowledge to solve unscripted and open-ended problems.

Project: Design of a Bulk Vitrification System for Hanford Salt-Cake Waste.

Duties & Responsibilities:

- Develop conceptual design for the bulk vitrification demonstration facility.
- Collaborate with Pacific Northwest National Laboratory to identify toxic byproducts of vitrification process.
- Conduct a land survey for location of the demonstration facility.
- Author the Procurement Specification for the Demonstration Bulk Vitrification System.

Key Highlights:

While at Hanford, I assisted in the development of new bulk vitrification technology. Bulk vitrification allows for the glassification of waste inside a container suitable for land disposal. I authored the *Procurement Specification for the Demonstration Bulk Vitrification System*. The document communicates the functional, performance, interface, and system design requirements for the vitrification facility. The facility was used as a forum for enhanced testing capability, including the capability to test waste processing under radioactive conditions. This work provided me with greater understanding and appreciation for highly complex, multi-disciplinary projects that involve collaboration across industry partners, national laboratories, and governmental agencies.

SELECT RESEARCH ACTIVITIES

DYNAMICS & CONTROL OF LRAS FOR HAPTIC FORCE GENERATION

Google, Mountain View, CA 2019 – 2023

Fundamental Research Question:

Can Haptic Force Generation be Enhanced Through Improved Modeling and Control?

Activities:

- Developed novel haptic actuators capable of broad-spectrum resonance.
- Authored the *LRA Handbook of Modeling and Control* to support ongoing LRA research within Google.
- Developed multi-mode linear and nonlinear models of LRAs.
- Developed an LRA characterization framework and testing protocol.
- Developed novel haptic effects that exhibit force profiles that cannot be produced by standard haptic libraries.
- Developed software framework to facilitate rapid haptic profile development and testing.

Outcome and Value:

The range and diversity of appreciable forces generated by LRAs is extended. Billions of smart phones, smart watches, and other consumer devices that use LRAs can be enhanced.

ADAPTIVE MANUFACTURING

PaR Systems, Shoreview, MN 2018 – 2019

Fundamental Research Question:

Can CAD-to-CAM Processes be Adapted for In-situ Parts that Diverge from CAD Models?

Activities:

- Developed methodology for morphing nominal CAD and machining data to in-situ parts.
- Developed and implemented computationally efficient software framework for executing morphing methodology.
- Oversaw proof-of-concept testing, and conversion of methodology into production solution.

Outcome and Value:

This R&D effort resulted in the development of state-of-the art adaptive manufacturing software. The capabilities of which are both pragmatic and unique, providing a significant technical differentiator for PaR Systems. A patent for this technology is currently pending.

AUGMENTED TELE-MANIPULATION

PaR Systems, Shoreview, MN 2018 – 2020

Fundamental Research Question:

Can Legacy Commercial Manual Tele-Manipulators be Augmented with Advanced Robotic Control Capabilities?

Activities:

- Oversaw development of electro-mechanical interface for legacy commercial manual tele-manipulators.
- Oversaw development of new kinematic/inverse kinematic and simulation models supporting effort.
- Directed prototyping efforts, algorithm development and implementation.

Outcome and Value:

Legacy manual tele-manipulators are prevalent within nuclear waste-stream processing facilities. This technology is facing obsolescence and supportability challenges that will significantly impact critical processes. Advanced robotic augmentation of these systems will enhance productivity, ergonomics, and ease-of-use, while also extending the serviceable life of these systems.

3D MACHINE VISION FOR ROBUST SEGMENTATION AND LOCALIZATION

PaR Systems, Shoreview, MN 2017 – 2018

Fundamental Research Question:

Can 3D machine vision data be used to provide robust segmentation and localization of LDP payloads?

Activities:

- Developed robust segmentation and localization algorithms based on raw point-cloud data.
- Oversaw development and implementation of capabilities into production firmware.

Outcome and Value:

This R&D effort significantly enhanced the robustness of the LDP for identifying product in unstructured environments. Deploying this product enhancement resulted greater productivity and end-user satisfaction. The development was also a key driver in numerous after-market sales.

ON-LINE TIME-OPTIMAL TRAJECTORY SYNTHESIS FOR FLEXIBLE MACHINES

CAMotion Cranes, Atlanta, GA.....2011 – 2013

Fundamental Research Question:

Can time-optimal rest-to-rest trajectories for highly flexible robots be generated on-line?

Activities:

- Developed constraint framework for defining generalized spatial trajectories with obstacle avoidance.
- Incorporated ongoing developments in Command Shaping theory into constraint framework to account for flexible dynamics.
- Derived and implemented computationally efficient solution methodology.
- Investigated computational cost of solution method.

Outcome and Value:

This disruptive technology served as a keystone differentiator between the company's robotic solutions and conventional robotic automation products. The technology significantly reduces implementation costs of robotic material handling systems by 1) reducing integration time, and 2) increasing the available throughput of a given robot.

PRAGMATIC ROBUST-COMMAND SHAPING FOR INDUSTRIAL MACHINES

CAMotion Cranes, Atlanta, GA.....2008 – 2010

Fundamental Research Question:

Can robust command shaping be used to control flexible machines without detrimental latency and time-consuming frequency characterization?

Activities:

- Developed framework for defining command shaping constraint sets that are subsequently used for deriving time-optimal and robust command shapers.
- Architected numeric optimization algorithm for generating time-optimal and robust command shapers.

Outcome and Value:

The outcome of this effort resulted in the creation of a class of robust command shapers for industrial cranes and large Cartesian robots that have subsequently been deployed on hundreds of flexible machines throughout the world. This family of command shaping filters is unique in the field of flexible machine control. They represent a significant improvement in robustness and latency compared to conventional command-shaping filters. Furthermore, this research resulted in the creation of a development framework with which flexible machines not considered here can benefit. This technology has been the cornerstone of the Expertoperator™ product – a world-class crane control platform that has yet to be surpassed in terms of performance.

WORKSPACE-ACCESSIBLE COLLISION AVOIDANCE FOR HUMAN OPERATED CRANES

CAMotion Cranes, Atlanta, GA 2008 – 2010

*Fundamental Research Question:****Can a control strategy be developed that permits operators to access the entire workspace, avoid collisions between the load and surrounding obstacles, and permits the crane to react responsively to commands?****Activities:*

- Conducted market study analyzing a 20-year span of crane accident reports from the primary metal industry.
- Developed first-of-kind stacker-crane collision avoidance system incorporating 3D-physics-based collision prediction and passive velocity constraint algorithms.

Outcome and Value:

These research efforts produced the most capable collision avoidance system for stacker cranes to date. While capable of mitigating over 90% of the historical collision types present in the primary metals industry, the system also permits 100% workspace access with no detrimental kinematic restrictions on crane speed or acceleration.

NONLINEAR INPUT SHAPING

Georgia Institute of Technology, Atlanta, GA 2005 – 2008

*Fundamental Research Question:****How do hard-nonlinearities affect the performance of input-shaped systems? How can detrimental effects be mitigated?****Activities:*

- Developed deconvolution analysis technique for assessing vibration-inducing attributes of arbitrary commands.
- Used developed technique to evaluate effects of hard-nonlinearities on input-shaping filters.
- Derived and implemented strategies for mitigating the detrimental effects of rate limiting, dead-zone, backlash, and saturation on input-shaped signals.
- Developed theoretical construct called the *command space* for understanding the cause and mitigation of overcurrenting on system using negative input shapers.
- Evaluated oscillatory effects of finite-state actuation on input shaping.

Outcome and Value:

These research efforts represent the first thorough investigation of input shaping in the context of hard-nonlinearities. The theoretical foundations established provide a unified framework for analyzing input-shaped systems. The ubiquitous presence of nonlinear actuation within every facet of industry precluded a large number of systems from using ordinary input shaping techniques. Thus, the direct result of this research was to tremendously enlarge the application space of input shaping. This research is the capstone of my doctoral work, and serves to fulfill a personal desire instilled during my first research encounter: to create new and pragmatic knowledge.

ROBUST FIDUCIAL TRACKING USING MACHINE VISION

Georgia Institute of Technology, Atlanta, GA 2003 – 2007

*Fundamental Research Question:****Can the state-of-the-art in machine vision be used for high-speed fiducial tracking in unstructured environments?****Activities:*

- Identified sampling limitations in industrial vision systems.
- Collaborative effort mitigated sampling limitations by dynamic adjustment of acquisition pixels.
- Supervised development of dynamically parameterizable blob-selection criteria.
- Supervised development of multi-blob fiducial for obstruction mitigation.

Outcome and Value:

During the course of this project I collaborated with researchers from the Zürich University of Applied Sciences, and Industry Partner, Logan Aluminum. Our joint efforts resulted in a fiducial tracking algorithm used for sensing hook swing on industrial bridge cranes. The utility of this sensing technology is that it is robust to visual obstructions, and highly reflective environments, where ordinary machine vision techniques fail. This work exposed me to research outside my field of controls, and thus served to broaden my research horizons. It also provided me valuable industry and academic ties. This research formed foundational pillars upon which Cranevision™ was developed. Cranevision™ is a world-class crane safety system deployed on hundreds of industrial cranes at world-wide.

OPERATIONAL EFFECTS OF CRANE INTERFACE DEVICES

Georgia Institute of Technology, Atlanta, GA 2005 – 2008

Fundamental Research Questions:

What is the influence of conventional interfaces on the operational performance of dynamically compensated cranes? In light of dynamic compensation, can a more efficient crane interface be developed?

Activities:

- Constructed cognitive operator model, and human-in-the-loop model for identifying shortcoming of conventional interface devices.
- Developed a visual human/machine interface for simplifying crane-positioning tasks.
- Developed framework to classify crane trajectories.
- Utilized framework to assess efficiency effects of developed and conventional interface devices.

Outcome and Value:

The results of these tasks were used to produce a commercially available human/machine interface for crane positioning. The technology was installed on a 35-ton crane at industry partner, Logan Aluminum. Significant efficiency advantages of the developed visual interface were demonstrated in an industrial setting. The work expanded my research experience to the field of human factors. I am more keenly aware of the issues involved with integrating automation technology with human control.

COMBINING INPUT SHAPING AND FEEDBACK CONTROL FOR INCREASING POSITIONING PRECISION ON SYSTEMS WITH FLEXIBLE DYNAMICS

Georgia Institute of Technology, Atlanta, GA 2003 – 2005

Fundamental Research Question:

Can closed-loop input shaping be used advantageously to control a nonlinear and non-collocated system?

Activities:

- Developed analytical model of vector drive and induction motor actuation systems.
- Theoretical foundation established for quantifying effects of nonlinearities on input shaping.
- Conducted simulated and experimental stability analysis of closed-loop input shaping architecture.
- Implemented closed-loop input shaping control on 10-ton bridge crane.

Outcome and Value:

The direct result of these efforts was a control architecture enabling precise positioning, disturbance rejection, and motion-induced oscillation suppression on non-collocated systems with flexible dynamics. Significant headway was made in forming a framework for the stability analysis of shaper-in-the-loop systems. Principles were established for understanding the detrimental effects of nonlinearities on input shaping. This research resulted in a granted US patent for the control architecture. Questions arising from this research helped me to identify the scope of my Ph.D. dissertation. I also gained valuable hands-on experience in control implementation on industrial PLC's, vector drives, and induction motors.

ELIMINATING HEAD-LOSS IN HYDRAULIC VANE PUMPS

Walla Walla University, College Place, WA 2002

Fundamental Research Question:

Can the efficiency of hydraulic vane pumps be significantly increased?

Activities:

- Developed analytical and empirical models of fluid flow for commercial vane pumps.
- Identified and quantified sources of energy loss in typical pump designs.
- Mitigated head-loss through novel kinematic and geometric redesign.
- Developed analytical and empirical models in conjunction with computer simulations of new pump design to verify specification compliance.
- Performed vibration, failure, and manufacturability analyses on developed pump design.

Outcome and Value:

I was first made aware of the need for high efficiency hydraulic pumps while investigating alternatives to traditional automobile transmissions. It was from that initial exposure, and subsequent study into the subject of innovative continuously variable transmissions that prompted my examination into the development of a high-efficiency vane pump. Research findings were presented at my local ASME student chapter, as well as the ASME Region VIII Student Conference in 2003. This work constituted my first formal research project, and sparked my desire to pursue graduate school where I could be involved in other research endeavors.

TEACHING ACTIVITIES

ADJUNCT ASSOCIATE PROFESSOR & PART-TIME INSTRUCTOR

Georgia Institute of Technology, Atlanta, GA 2010 – Present

Advanced Mechatronics (Graduate Course)

The focus of this course is a semester-long team project emphasizing design methodology and industrial best practices in the creation of a sophisticated mechatronic system. Systems include a variety of sensing modalities, actuators, micro controllers, and rapid prototype mechanical components. Issues of product liability, intellectual property, and safety are a part of the curriculum.

Advanced Control Design & Implementation (Graduate Course)

One objective of this course is to learn advanced control techniques such as: optimal control, tracking control, repetitive control, adaptive control, linear and nonlinear command shaping. A second objective is to implement these control technique both on simulated and real mechatronic systems.

Creative Decisions and Design (Undergraduate Course)

The objective of this course is to learn the fundamental principles of the design process. This is accomplished through lectures in a lecture hall setting, and practice through lab work. Properly learning the design process and how to use it is essential for solving unstructured and open-ended problems.

Dynamics of Rigid Bodies (Undergraduate Course)

The objective of this course is to learn kinematics and kinetics of particles and rigid bodies in one, two, and three dimensions. Topics include Particle Motion, Planar Kinematics, Newton-Euler Analysis, Angular Velocity/Accelerations in Three Dimensions, Euler Angles, Rotation Matrices, Angular Momentum, Inertia Properties, Principal Moments & Axes of Inertia, Impact/Impulse/Momentum Principles, Work-Energy Analysis of Conservative & Non-conservative Bodies.

Emerging Technology Law (Undergraduate Course)

This course is concerned with the practice of engineering in the context of the legal system. Two principal areas of focus are product liability and intellectual property. One objective of this course is to understand how emerging technology can be protected through the patent system, and the role of engineers in this endeavor. A second objective is to understand the role of engineers in identifying and mitigating issues of product liability.

Value

A core component of my teaching philosophy is put into practice and refined during my teaching, namely, my focus on interjecting real-world engineering practice into the class room. Pragmatically, this focus results in student application of course content onto current or recent industrial projects at CAMotion Cranes, PaR Systems, and Finity Engineering.

PH.D. TEACHING PRACTICUM

Georgia Institute of Technology, Atlanta, GA Fall 2006

Course Instructor: Dr. Farrokh Mistree (Woodruff Zeigler Outstanding Educator 2001)

Practicum Adviser: Dr. Aldo Ferri (Roane Beard Outstanding Teacher 2008)

The teaching practicum is a formal investigation and practice of the fundamental aspects of engineering education. Grant proposal composition, student advising, course development, student evaluation, professional development, professional service, industry and academia relationships, and teaching/learning styles comprise the topical framework of the course. A knowledge base of these subjects is obtained through class lectures and discussion, then pragmatic/experiential knowledge is gained through collaborative involvement with a sponsoring Adviser.

During the teaching practicum, I collaborated with Dr. Aldo Ferri for the course ME 2016 – Computing Techniques. I selected a partnership with Dr. Ferri because he possesses an extraordinary ability for imparting knowledge, and personal responsibility to his students. Dr. Ferri imbues his students with personal ownership for one's own learning. Personal ownership fosters disciplined academic behavior. He is also able to impart

a depth and breadth of subject matter that is cohesive, thorough, and inextricably linked with prior knowledge. The keystone of his teaching ability is scrupulous organization that serves students in two ways; first, by helping them to connect new information with prior knowledge; and second, by demonstrating good dissemination practices.

Value

I worked closely with Dr. Ferri during the semester to plan course content, create new lecture material, and prepare and present class lectures. The value of conducting these activities in collaboration with Dr. Ferri is that I obtained pragmatic knowledge of engineering education that was shaped by expert oversight.

NSF STUDENT & TEACHER ENHANCEMENT PARTNERSHIP FELLOW

Marietta High School, Marietta, GA 2005 – 2006

The Student and Teacher Enhancement Partnership (STEP) program seeks to improve mathematics and science performance of Atlanta-area high school students, while at the same time enhancing the teaching-related communication and leadership skills of Georgia Tech students. This is accomplished by partnering Georgia Tech students who possess scholarly expertise with partner high schools.

As a STEP fellow, I participated in training workshops covering learning pedagogy, classroom management, and learning/lecturing styles. During the 2005-2006 academic year, I collaborated with math and science teachers at Marietta High School to develop lecture material, conduct student instruction, mentoring, and tours of Georgia Tech facilities. I also instituted an after-school engineering club where participants learned about fundamental engineering principles through activity-based team projects and competitions. 15-20 students regularly attended the weekly club events.

Value

A key element of my teaching ability was refined during this experience. I developed my ability to assess the initial knowledge state of my students. This is a critical step toward a principal goal of imparting knowledge in a manner that is connected to prior knowledge. I also became more clearly aware of the distinction between teaching students information, and teaching students how to learn.

GRADUATE TEACHING ASSISTANT

Georgia Institute of Technology, Atlanta, GA Fall 2003

System Dynamics and Controls (ME 3015)

Dr. Aldo Ferri (Roane Beard Outstanding Teacher 2008)

My principal responsibility as a teaching assistant was to provide out-of-class tutoring to students. I also developed and delivered in-class lectures, and graded homework assignments.

Value

As a tutor, I assisted students in a one-on-one, or small-group setting. These opportunities allowed me to better understand the difficulties some students face when learning challenging material. I learned that difficult material is more easily assimilated when it is presented in its greater context. This means that both the utility and objective of using the material should be communicated.

DIRECTOR OF ROCK CLIMBING & BACKPACKING PROGRAMS

Glacier View Ranch, Ward, CO 1998 – 2002

As the director of the rock climbing and backpacking programs at Glacier View Ranch, my principal responsibility was to teach rock climbing and backpacking skills to course participants. During my five three-month summer terms between 1998 and 2002, I taught 20 1-week courses to approximately 300 participants ranging in age from 10 to 18 years old. The programs were activity-based, and involved backpacking and rock climbing expeditions in the mountains of Colorado. My other responsibilities included training and supervising assistants, ensuring compliance with the American Camping Association, and managing inventories.

Value

As a director of high-risk activities for adolescent and teenage youth, I have assumed weighty responsibilities for participant safety, while at the same time facilitating an exciting and challenging learning environment. This endeavor required a clear vision of course objectives and educated foresight of potential risk in order to provide an enjoyable and safe learning experience. Conducting these activity-based lessons forged my abilities to communicate, manage personnel, achieve objectives, and teach, while assuming the tremendous responsibility of ensuring safety.

ADVISING ACTIVITIES

INTERNATIONAL BACHELORS THESIS STUDENTS

Christoph Staheli	<i>Fiducial Tracking in Presence of Parametric Noise</i>	2004
Rolf Weiss	<i>Multi-Dot Fiducial Positioning Algorithm</i>	2005
Stefan Locher	<i>STL to SCL Crane Controller Transition</i>	2006
Jurg Suter	<i>Mobic Touch Screen Crane Interface</i>	2006
Johannes Fisch	<i>Robust Fiducial Tracking Algorithm</i>	2007
Philipp Andersch	<i>R-Analysis of Hard-nonlinearities on Input Shapers</i>	2007 – 2008
Martin Utz	<i>Virtual Safety Walls for Cartesian Robots</i>	2008
Martin Schibli	<i>Testing of a Siemens Embedded Controller</i>	2009

UNDERGRADUATE STUDENTS

April Pritchard	<i>Nonlinear Crane Drive Identification</i>	2004
Terry Hall	<i>Touch Screen Interface Accuracy Evaluation</i>	2005
Jonathan Fonseca	<i>Crane Operator Experiments</i>	2006 – 2007
Joshua Spiers	<i>Crane Operator Experiments, Effects of Backlash</i>	2006 – 2007
Brandon Terrell	<i>Detrimental Effects of Saturation on Input Shaping</i>	2007
Animesh Aga	<i>3D Crane Simulation</i>	2007
Vig Kalyanasundaram	<i>3D Bridge Crane Simulation</i>	2007
Aayush Daftari	<i>Command Space Experiments for UMZV Shaping</i>	2007 – 2008
Paul Jurek	<i>Obstacle Avoidance for Cartesian Robots</i>	2009

GRADUATE STUDENTS

Patrick (Will) Cross	<i>Effects of Dead-Zone on Input Shaping</i>	2006
Shashvat Prakash	<i>Effects of Dead-Zone on Input Shaping</i>	2006
Sebastian Sachse	<i>Graphical Interface for Commanding Crane Motion</i>	2008
James Potter	<i>Trajectory Generation for Cartesian Robots</i>	2009
Chen (Kelvin) Peng	<i>Robust Input Shapers for Cranes</i>	2010
Ehsan Maleki	<i>Control of Human-Operated Machinery with Flexible Dynamics (PhD Thesis)</i>	2013
Yashdeep Narkhede	<i>Polygon Offsetting & Crane Automation</i>	2015
Christopher Adams	<i>Modeling and Control of Backdrivable Flexible Systems (PhD Thesis)</i>	2017
Arnoldo Castro	<i>Control of a Two Wheeled Inverted Pendulum Transporter (PhD Thesis)</i>	2019
Henry Luk	<i>Survey of Haptic Control & Actuators</i>	2020
Alison Jenkins	<i>Human Factors in Haptics</i>	2020 – 2021
Colin Lyman	<i>Dynamics and Control of Haptic Motors</i>	2020
Joo-Won Kang	<i>Dynamics and Control of Haptic Motors</i>	2020
Ryan Schmidt	<i>Modeling of Linear Resonance Actuators</i>	2020 – 2021
Tyler Rome	<i>Discrete Input Shaping</i>	2021– 2022

PUBLICATIONS ARISING FROM COLLABORATION

Numerous refereed publications have been produced from these collaborative efforts. These publications are included in the *Publications* section of this document.

PUBLICATIONS

REFEREED JOURNAL ARTICLES

W. Singhose, J. Lawrence, **K. Sorensen**, and D. Kim, "Applications and Educational Uses of Crane Oscillation Control," *FME Transactions*, vol. 34, pp. 175-183, 2006.

K. L. Sorensen, W. E. Singhose, and S. Dickerson, "A Controller Enabling Precise Positioning and Sway Reduction in Bridge and Gantry Cranes," *Control Engineering Practice*, vol. 15, pp. 825-837, 2007.

J. R. Huey, **K. L. Sorensen**, and W. E. Singhose, "Useful Applications of Closed-Loop Signal Shaping Controllers," *Control Engineering Practice*, vol. 16, pp. 836-846, 2008.

K. L. Sorensen and W. E. Singhose, "Command-Induced Vibration Analysis Using Input Shaping Principles," *Automatica*, vol. 44, pp. 2392-97, 2008.

K. L. Sorensen, A. Daftari, W. E. Singhose, and K. Hekman, "Negative Input Shaping: Eliminating Overcurrenting & Maximizing the Command Space," *ASME Journal of Dynamic Systems, Measurement, and Control*, vol. 130, pp. 0610121-27, 2008.

K. L. Sorensen, K. Hekman, and W. E. Singhose, "Finite-State Input Shaping," *IEEE Transactions on Control Systems Technology*, vol. 18, pp. 664-672, 2010.

K. L. Sorensen, P. W. Cross, W. E. Singhose, S. Prakash, "Vibration Analysis and Mitigation of Dead-Zone on Systems Using Two-Impulse Zero Vibration Input Shaping," *ASME Journal of Computational and Nonlinear Dynamics*, vol. 6, pp. 011011-1-7, 2011

K. L. Sorensen, J. Danielson, S. Dickerson, W. E. Singhose, H. Fisch, and U. Glauser, "An Industrial Bridge Crane Manipulation System with Multiple Human Interfaces," *International Journal of Control, Automation, and Systems*. (Submitted).

K. L. Sorensen, R. Schmidt, A. Jenkins, C. Lyman, W. Singhose, F. Schlagenhauf, K. Dobson, "Electromagnetic Model of Linear Resonant Actuators," *ASME Journal of Dynamic Systems, Measurement, and Control*, vol. 145, pp. 0510031-39, 2023.

T. Rome, W. Singhose, **K. Sorensen**, K. Dobson, F. Schlagenhauf, "Discrete Shapers for Reducing Residual Acceleration in Linear Resonant Actuators," *Journal of Sound and Vibration*. (Submitted).

K. L. Sorensen, J. Spiers, T. Hall, S. Dickerson, W. Singhose, "Design and Performance Evaluation of a Visual Operator Interface for Cranes," *Automation*. (Submitted).

REFEREED CONFERENCE PROCEEDINGS

K. Sorensen, W. Singhose, and S. Dickerson, "A Controller Enabling Precise Positioning and Sway Reduction in Cranes with On-Off Actuation," Proceedings of the 16th IFAC World Congress, Vol. 16-1, Prague, 2005.

K. Hekman, C. Staheli, **K. Sorensen**, and W. Singhose, "Measuring Crane Payload Swing Angle Through Computer Vision," Proceedings of the *International Symposium on Flexible Automation*, Osaka, Japan, 2006.

W. Singhose and **K. Sorensen**, "Manipulation of Flexible Space Structures: Effects of Command Shaping and Human Interfaces," *ICRA Workshop on Space Robotics*, Rome, Italy, 2007.

K. Sorensen and W. Singhose, "Oscillatory Effects of Common Hard Nonlinearities on Systems Using Two-Impulse ZV Input Shaping," Proceedings of the *American Control Conference*, pp. 5539-5544, New York City, NY, 2007.

K. L. Sorensen, J. B. Spiers, and W. E. Singhose, "Operational Effects of Crane Interface Devices," Proceedings of the 2nd IEEE Conference on Industrial Electronics and Applications, pp. 1073-1078, Harbin, China, 2007.

J. Suter, D. Kim, W. Singhose, **K. Sorensen**, and U. Glauser, "Integrating A Wireless Touchscreen Into A Bridge Crane Control System," Proceedings of the *IEEE/ASME International Conference on Advanced Intelligent Mechatronics*, pp. 1-6, Zürich, Switzerland, 2007.

K. L. Sorensen, P. W. Cross, W. E. Singhose, and S. Prakash, "Analysis and Mitigation of Dead-Zone Effects on Systems Using Two-Impulse ZV Input Shaping," Proceedings of the *ASME IDETC/CIE 6th International Conference on Multibody Systems, Nonlinear Dynamics, and Control*, Las Vegas, USA, 2007. DETC2007-35592.

P. Andersch, **K. Sorensen**, and W. E. Singhose, "Effects of Rate Limiting on Common Input Shaping Filters," Proceedings of the *10th WSEAS International Conference on Automatic Control, Modelling and Simulation*, Istanbul, Turkey, 2008.

K. Sorensen, H. Fisch, S. Dickerson, W. Singhose, and U. Glauser, "A Multi-Operational-Mode Anti-Sway & Positioning Control for an Industrial Bridge Crane," Proceedings of the *17th IFAC World Congress*, Seoul, Korea, 2008.

K. L. Sorensen, J. Danielson, and W. E. Singhose, "Anti-Sway and Positioning Control for an Industrial Bridge Crane with Multi-Mode Dynamics," Proceedings of the *International Symposium on Flexible Automation*, Atlanta, GA, USA, 2008.

J.J. Potter, **K. L. Sorensen**, and W. E. Singhose, "Efficient Method for Generating Pick-and-Place Trajectory over Obstacles," Proceedings of the *IASTED Technology Conferences*, Cambridge, MA, USA, 2010.

K.C.C Peng, **K. L. Sorensen**, W. E. Singhose, and J. Danielson, "Sway Control of a Relay-Driven Crane with Asymmetrical Acceleration and Deceleration," Proceedings of the *IASTED Technology Conferences*, Cambridge, MA, USA, 2010.

A. Castro, W. Singhose, X. Liu, **K. Sorensen**, and E. C. Kwak, "Modeling and Experimental Testing of Hoverboard Dynamic Behavior," Proceedings of the *ASME Dynamic Systems and Control Conference*, Tysons Corner, VA, USA, 2017.

K. Sorensen, W. Singhose, "Wheeled Inverted Pendulum Control and Slip Dynamics," Proceedings of the *IEEE International Conference on Control and Automation*, Anchorage, AK, USA, 2018.

M. J. Kim, **K. Sorensen**, "Comparison of Coulomb and Brush Tire Models for Characterizing Tractive Force in WIP Systems," Proceedings of the *IEEE International Conference on Control and Automation*, Anchorage, AK, USA, 2018.

F. Schlagenhauf, W. Singhose, **K. Sorensen**, K. Dobson "Command-Shaping Control of Linear Resonant Actuators for Haptic Force Generation," Proceedings of the *21st IFAC World Congress*, Berlin, Germany, 2020.

T. Rome, W. Singhose, K. Dobson, **K. Sorensen**, F. Schlagenhauf, J. Kang "Impact of Input Shaper Discretization on Linear Resonant Actuators for Haptic Feedback," Proceedings of the *IEEE International Symposium on Industrial Electronics*, Anchorage, Alaska, 2022.

REFEREED INDUSTRIAL CONFERENCE PROCEEDINGS

K. Sorensen, "Expert Operator Control for Increasing Safety, Productivity, and Operability of Cranes," *AISTech Conference Proceedings*, Atlanta, GA, USA, 2012.

K. Sorensen, "Snagging Incidents and Prevention for EOT Cranes – A Case Study," *AISTech Conference Proceedings*, Cleveland, OH, USA, 2020. (Accepted).

PATENTS

K. Sorensen, W. Singhose, and S. Dickerson, “Combined Feedback and Command Shaping Controller for Multistate Control with Application to Improving Positioning and Reducing Cable Sway in Cranes,” US Patent No. 7,970,521, 2011.

K. Sorensen, W. Singhose, “Crane Motion Control,” US Patent No. 9,776,838, 2017.

K. Sorensen, M. Adam, C. Miles, B. Halonen, “Sway Mitigation for Material Handling,” US Application 16/088385, 2021.

K. Dobson, F. Lagenhauf, W. Singhose, **K. Sorensen**, N. Sinatra, “Systems and Methods for Customizing a Haptic Output of a Haptic Actuator of a User Device,” Int. Application WO 2022/146426, 2022.

THESES

K. L. Sorensen, “A Combined Feedback and Command Shaping Controller for Improving Positioning and Reducing Cable Sway in Cranes,” *Woodruff School of Mechanical Engineering*, Masters Thesis. Atlanta: Georgia Institute of Technology, 2005.

K. L. Sorensen, “Operational Performance Enhancement of Human Operated Flexible Systems,” *Woodruff School of Mechanical Engineering*, PhD. Thesis. Atlanta: Georgia Institute of Technology, 2008.

JOURNAL PEER REVIEW

Mechatronics. A Journal of the International Federation of Automatic Control (IFAC).
International Journal of Control, Automation, and Systems.
Robotics and Automation Letters. A Journal of the IEEE Robotics & Automation Society.
Control Theory & Applications. A Journal of the Institution of Engineering and Technology (IET).
Journal of Dynamic Systems, Measurement, and Control. A Journal of the ASME.
Transactions on Mechatronics. A Journal of IEEE & ASME.
Transactions on Human-Machine Systems. A Journal of IEEE.
Journal of Measurement. A Journal of the Int. Measurement Confederation (IMEKO).
Journal of Engineering Science and Technology.
Engineering Science and Technology, an International Journal.
Soil and Tillage Research, an International Journal.

CONFERENCE PEER REVIEW

Asian Control Conference
IEEE/ASME International Conference on Advanced Intelligent Mechatronics.
IEEE International Conference on Robotics and Automation.
AACC American Control Conference.
IASTED Conference on Intelligent Systems and Control.
ASME Conference on Engineering Systems Design and Analysis.

CONFERENCE SESSION CHAIR

Session Co-Chair. "Industrial Control Systems," *IEEE International Conference on Control and Automation*, Anchorage, AL, USA, 2018.

OTHER POSITIONS

Southern Adventist University, Engineering Industry Advisory Board.

SCHOLARSHIPS, FELLOWSHIPS, AWARDS, & HONORS

Interviewed Contributor for <i>Hoist Magazine</i>	2023
- Featured industry contributor for the article “The Lowdown on Load Sway”, Sept. 12, 2023. - Article featured Expertoperator™ and Cranevision™ motion control technologies.	
Effective Teacher Commendation	2020
- Woodruff School of Mechanical Engineering Annual Teaching Evaluation. - Received Effective Teacher Ratings of 4.6 and 4.5. Scores are “very good and above average for GWW School instructors overall.”	
Interviewed Contributor for <i>Hoist Magazine</i>	2019
- Contributed technical and industry insights for the article “Sway Away”, June 19, 2019. - Article featured Expertoperator™ anti-sway technology.	
Named One of 125 SAU Alumni Who Made a Difference in the World	2017
- Featured Alumnus in <i>Columns</i>, the magazine of Southern Adventist University. - Named one of 125 alumni who made a difference in the world since schools inception in 1892.	
Effective Teacher Commendation	2017
- Woodruff School of Mechanical Engineering Annual Teaching Evaluation. - Received Effective Teacher Rating of 4.76. Score is “very good and well above average for GWW School instructors overall.”	
Featured Alumnus in <i>By Design</i> , a publication of the Walla Walla University School of Engineering	2014
Article “Sorensen Advances Industrial Crane Technology Throughout the World.”	
Control Engineering Practice Most Cited List	2012
2nd Most Cited Between 2007 – 2012 for Article Entitled <i>A Controller Enabling Precise Positioning and Sway Reduction in Bridge and Gantry Cranes</i>.	
AIST Certificate of Recognition	2012
In appreciation for the presentation entitled Expert Operator Control for Increasing Safety, Productivity, and Operability of Cranes.	
ARCS Foundation Scholar	2007
- Recognition of contributions to the advancement of science and technology. \$6K per year – renewable.	
IEEE Conference on Industrial Electronics & Applications. Best Paper Finalist	2007
Top 5 papers selected as finalists from over 1000 submissions.	
NSF Student & Teacher Enhancement Partnership (STEP) Fellow	2006
- Selected to improve math and science performance of Atlanta-area high school. - Facilitates student instruction, enrichment and mentoring, and teacher professional development. \$30K/year award.	
IFAC Best Application Paper	2005
- Best application papers selected from among conference submissions. - Paper published in special issue of Control Engineering Practice for best application papers.	

1 st Place: Regional ASME Old Guard Oral Competition	2003
• 20 Minute technical presentation of research activities delivered. • Judging criteria based on well-developed content, organization, delivery, effectiveness, and discussion.	
USAA National Collegiate Engineering Award	2002
• Award based on academic performance, dependability, leadership, enthusiasm, dedication to self-improvement, attitude, and responsibility. • Nominated by Walla Walla College engineering faculty.	
National Dean's List	2002
• Students previously awarded "Dean's List" status eligible. • Recognition of outstanding academic and community achievement.	
Who's Who Among Students in American Universities	2002, 2003
• Service to school and community. • Curricular and extra-curricular excellence recognized.	
WWC Distinguished Dean's List	2001, 2002
• Recognition for perfect grade point average.	
WWC GPA Transfer Scholarship	2000, 2001
• High GPA-based award made available to incoming transfer students. • \$2K per year – renewable.	
Kenneth Schmidt Scholarship	2000, 2001
• Based on scholarship, citizenship, spirituality, and extra-curricular activities. • \$1K per year.	
Youth Service Organization Scholarship	2000
• Recognition of 10-month missionary service. • \$3K per year.	
SAU Calculus Sequence Award	1999
• Students who have completed Calculus I-III and Differential Equations eligible. • Selected by math faculty. • Student with highest grade average throughout the calculus sequence awarded.	
SAU Distinguished Dean's List	1998, 1999
• Recognition for perfect grade point average.	
Christian Service Volunteer Scholarship	1998 – 2002
• Recognition of charitable service conducted between academic years. • \$1K per year.	
SAU Calculus I Award	1998
• Freshman Calculus I students eligible. • Selected by math faculty. • Top Calculus student.	
SAU ACT Renewable Scholarship	1997, 1998
• High ACT-score-based award made available to incoming freshmen students. • \$3K per year – renewable.	

President's Award for Educational Excellence	1997
• High grade point average. • High achievement in national standardized tests.	
USAA All-American Scholar	1996
• Exceptional academic achievement. • Well balanced involvement with extra-curricular activities.	
John Philip Sousa Band Award	1996
• Excellence in musical achievement. • Recognizes outstanding dedication and superior musicianship.	
Frederick Chopin Piano Award	1995, 1996
• Excellence in piano performance.	

SPEAKING ENGAGEMENTS

<i>Plenary Speaker</i> – Georgia Institute of Technology, Atlanta, GA Kickoff Meeting for the Georgia Tech Crane Safety Research Center. “How to Make Cranes Safer with Technology: Cranevision”	Apr – 2024
<i>Keynote Speaker</i> – Walla Walla University, College Place, WA Annual Engineering Banquet “How to Talk to Social Workers & Other Advice for Engineers”	Feb – 2024
<i>Guest Lecturer</i> – Walla Walla University, College Place, WA Linear Systems Analysis ENGR 350 “Fundamentals of Bode Plots”	Oct – 2023
<i>Plenary Speaker</i> – Mechforum 2023, International Forum on Automotive and Mechanical Engineering, Osaka, Japan, and Virtual. “Transformative Crane Technology for Automotive Stamping Applications”	Jun – 2023
<i>Invited Talk</i> – Walla Walla University, Walla Walla, WA Engineering Colloquium “Advanced Crane Control, Material Handling, Adaptive Manufacturing, and Other Remarkable Engineering Projects”	Apr – 2023
<i>Invited Talk</i> – Overhead Crane and Hoist Innovation Virtual Conference “Anti-Sway and Beyond: Advanced Motion Control”	Oct – 2020
<i>Invited Course Instructor</i> – Huazhong University of Science & Technology, Wuhan China Taught 1-week intensive “Mechatronics Creative Decisions & Design” course.	Apr – 2019
<i>Invited Talk</i> – American Society of Safety Professionals, Tuscaloosa Chapter, Tuscaloosa, AL “Human Factors & Crane Safety”	Nov – 2018
<i>Academic Conference</i> – IEEE Int. Conference on Control and Automation, Anchorage, AK “Comparison of Coulomb and Brush Tire Models for Characterizing Tractive Force in WIP Systems”	Jun – 2018
<i>Academic Conference</i> – IEEE Int. Conference on Control and Automation, Anchorage, AK “Wheeled Inverted Pendulum Control and Slip Dynamics”	Jun – 2018
<i>Invited Talk</i> – Honda Manufacturing of America, Marysville, OH Presentation of Safety Technologies by Designated SMEs on Crane Safety & Control	Jun – 2018
<i>Professional Conference</i> – Manufacturing in America Conference, Detroit, MI “Crane Safety, Productivity, & Ease of Use with Expert Motion Technology”	Mar – 2018
<i>Invited Talk</i> – American Society of Safety Engineers, Alabama Chapter, Birmingham, AL “Motion Control for Enhanced Crane Safety”	Feb – 2018
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Advanced Mechatronics ME 6408 “Slip Dynamics & Control of Wheeled Personal Transporters”	Feb – 2018
<i>Professional Conference</i> – Automotive Safety Forum, Nissan, Murfreesboro, TN “Expertoperator™: Motion Control for Safety”	Sep – 2017

<i>Professional Conference</i> – Manufacturing in America Conference, Detroit, MI “Pragmatic Applications of Advanced Motion Control for Robots and Cranes”	Mar – 2017
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Advanced Mechatronics ME 6408 “Mechatronic Considerations of Unstable Two Wheeled Personal Transporters”	Feb – 2017
<i>Invited Talk</i> – TVA Crane & Rigging Coordinator Conference, Chattanooga, TN “Controls for Crane Safety”	Dec – 2016
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Advanced Mechatronics ME 6408 “Design Methodology & Practice”	Feb – 2016
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Advanced Mechatronics ME 6408 “Non-Collocated Control of System with Hard Nonlinearities”	Feb – 2015
<i>Invited Talk</i> – Robotic Ally Conference, Minneapolis, MN “Advanced Motion Control Technology & Industrial Material Handling”	Sep – 2014
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Creative Decisions & Design ME 2110 “Intellectual Property in Engineering”	Jun – 2014
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Advanced Mechatronics ME 6408 “Industrial Mechatronic Design”	Mar – 2014
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Advanced Controls and Implementation, ME 6404 “Pragmatic Control Architecture Synthesis”	Nov – 2013
<i>Invited Talk</i> – 20 th Annual AIST Crane Symposium, Pittsburgh, PA “Collision Protection for Industrial Cranes”	Jun – 2013
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Advanced Controls and Implementation, ME 6404 “Position Control of Machines with Input Shaping”	Feb – 2013
<i>Invited Talk</i> – AISTech, Atlanta GA “Expert Operator Control for Increasing Safety, Productivity, and Operability of Cranes”	May – 2012
<i>Guest Lecturer</i> – Walla Walla University, Walla Walla, WA Introduction to Engineering “The Design Process in Industry”	Nov – 2011
<i>Guest Lecturer</i> – Walla Walla University, Walla Walla, WA Kinematics “Multi-Mode Vibration Suppression”	Nov – 2011
<i>Invited Talk</i> – ASME Chapter at Georgia Institute of Technology, Atlanta, GA “The Design Process in Industry”	Jan – 2011

<i>Invited Talk</i> – RIA, AIA, & MCA Joint Conference, Orlando, FL “Advanced Control & the Role of Machine Vision”	Jan – 2011
<i>Invited Talk</i> – Southern Adventist University, Collegedale, TN Engineering Convocation “From Research to Industry – A Path to Commercialization”	Jan – 2011
<i>Academic Conference</i> – IASTED Technology Conference, Cambridge, MA “Efficient Method for Generating Pick-and-Place Trajectory over Obstacles”	Nov – 2010
<i>Guest Lecturer</i> – Massachusetts Institute of Technology, Cambridge, MA Graduate Level Course on Advanced Vibration Control “Mitigating the Detrimental Effects of Rate Limiting on Command Shaping”	Nov – 2010
<i>Invited Talk</i> – 17 th Annual AIST Crane Symposium, Pittsburgh, PA “Advanced Control Technology for Industrial Cranes”	Jun – 2010
<i>Invited Talk</i> – ASME Chapter at Georgia Institute of Technology, Atlanta, GA “From Research to Industry – A Path to Commercialization”	Feb – 2010
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Advanced Controls and Implementation, ME 6404 “Zero-Phase Error Tracking Control”	Nov – 2009
<i>Invited Talk</i> – Kyung Hee University, Gyeonggi-do, Korea “Applications and Commercialization of Crane Control Research”	Oct – 2009
<i>Invited Talk</i> – Korea Atomic Energy Research Institute, Daejeon, Korea “Advanced Crane Control for Nuclear Applications”	Oct – 2009
<i>Invited Talk</i> – Kumoh National University of Technology, Gumi, Korea “Applications and Commercialization of Crane Control Research”	Oct – 2009
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Advanced Controls and Implementation, ME 6404 “Command-Induced Vibration Analysis using Input Shaping Principles”	Sep – 2009
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Advanced Controls and Implementation, ME 6404 “Victor Diagrams for Vibration Analysis of Input Shapers”	Aug – 2009
<i>Guest Lecturer</i> – Georgia Institute of Technology, Atlanta, GA Creative Decisions and Design, ME 2110 “Customer Driven Crane Control Design”	Jun – 2009
<i>Academic Conference</i> – Int. Symposium on Flexible Automation, Atlanta, GA “Anti-Sway and Positioning Control for an Industrial Bridge Crane with Multi-Mode Dynamics”	Jun – 2008
<i>Academic Conference</i> – ASME IDETC/CIE 6 th Int. Conference on Multibody Systems, Nonlinear Dynamics, and Control, Las Vegas, NV “Analysis and Mitigation of Dead-Zone Effects on Systems Using Two-Impulse ZV Input Shaping”	Sep – 2007

Academic Conference – American Control Conference, New York City, NY
“Oscillatory Effects of Common Hard Nonlinearities on Systems Using Two-Impulse
ZV Input Shaping”

Jul – 2007