

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Axon Enterprise, Inc., Dedrone Holdings, Inc., and Skydio, Inc.

Petitioners,

v.

Airspace Systems, Inc.

Patent Owner

Case No. IPR2025-00629

U.S. Patent No. 10,514,711

**DECLARATION OF NIKOLAOS PAPANIKOLOPOULOS, PH.D.
IN SUPPORT OF PATENT OWNER RESPONSE AND
MOTION TO AMEND**

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List of Patent Owner Exhibits

Exhibit No.	Description
EX2001	U.S. Army Contract No. W15QKN-17-9-1022
EX2002	Smithsonian, National Air and Space Museum Letter to Mr. Banga, dated March 13, 2024
EX2003	Z. Yang and R. Sinnott, "Snake Detection and Classification using Deep Learning," in Proceedings of Hawaii International Conference on System Sciences (2021), https://scholarspace.manoa.hawaii.edu/server/api/core/bitstreams/f9f2de4d-ddaa-4984-9fc3-9bbca4e27247/content
EX2004	Q. Ji, "Object Detection and Recognition," https://sites.ecse.rpi.edu/~qji/CV/ObjectDetRecog2.pdf
EX2005	The National Science Foundation, "How to Radars Work?," https://www.eol.ucar.edu/content/how-do-radars-work
EX2006	Principles of Doppler Radar, http://ww2010.atmos.uiuc.edu/(Gh)/guides/rs/rad/basics/dpmod.rxml
EX2007	https://developer.apple.com/documentation/corelocation/configuring-your-app-to-use-location-services
EX2008	https://developer.apple.com/documentation/corelocation/cllocation
EX2009	https://developer.android.com/develop/sensors-and-location/location/retrieve-current
EX2010	https://developer.android.com/reference/android/location/Location
EX2011	https://www.merriam-webster.com/dictionary/autonomous

Exhibit No.	Description
EX2012	https://dictionary.cambridge.org/us/dictionary/english/-autonomous
EX2013	Declaration of Noah Moore
EX2014	Airspace Interceptor, Fully Autonomous Physical Mitigation System Designed to Detect, Capture or Ram Drone, https://www.airspace.co/airspace-interceptor/
EX2015	Smithsonian National Air and Space Museum, Donate a Personal Item, https://airandspace.si.edu/donate-item
EX2016	Smithsonian National Air and Space Museum, Roger Connor Bio, https://airandspace.si.edu/people/staff/roger-connor
EX2017	Smithsonian National Air and Space Museum, About the Collection, available at https://airandspace.si.edu/collections/about-collection (last visited July 14, 2025)
EX2018	Jointly Proposed Protective Order
EX2019	U.S. Patent App. No. 16/142,452 (from which U.S. Patent No. 10,514,711 issued), as filed (the “’452 App.”)
EX2020	Streaming, Definition of Streaming by Merriam-Webster (2016)
EX2021	Streaming definition and meaning, Collins English Dictionary (2018)
EX2022	R. Wang et al., “An Effective Image Denoising Method for UAV Images via Improved Generative Adversarial Networks,” <i>Sensors</i> vol. 18(7):1985 (2018), doi:10.3390/s18071985.
EX2023	A. Ahmad et al., “Noise and Restoration of UAV Remote Sensing Images.” <i>International Journal of Advanced Computer Science</i>

Exhibit No.	Description
	<i>and Applications</i> , vol. 11, no. 12 (2020) doi:10.14569/ijacsa.2020.0111222
EX2024	Curriculum Vitae of Dr. Nikolaos Papanikolopoulos
EX2025	Declaration of Nikolos Papaniklopoulos, Ph.D., in support of Patent Owner's Response and Motion to Amend

I, Nikolaos Papanikolopoulos, of Minneapolis, Minnesota, declare that:

I. INTRODUCTION

1. I have been retained by Patent Owner Airspace Systems, Inc. in this *inter partes* review (IPR) proceeding number IPR2025-00629, filed by Petitioners Axon Enterprise, Inc., Dedrone Holdings, Inc., and Skydio, Inc. I understand that this IPR proceeding relates to U.S. Patent No. 10,514,711 (the '711 patent).

2. I have been asked to provide my objective, independent analysis of the '711 patent in view of the prior art references cited in the Petition and to provide my opinion regarding the allegations in the Petition and substitute claims proposed by Patent Owner.

3. I have based my opinions on the information available to me as of the date of this declaration. I understand that additional information may become available after this declaration is submitted. If I become aware of additional information following my submission of this declaration I may, if I am permitted, offer additional opinions (including by amending and/or supplementing this declaration) taking into account such new information.

4. I am not currently, nor have I ever been, an employee of Airspace Systems, Inc., its subsidiaries, parent organizations, or affiliates. I received no compensation for this declaration beyond my normal hourly compensation based on my time actually spent working on this IPR. I will not receive any added

compensation based on the outcome of this or any other IPR, or any other proceeding, involving the '711 patent.

II. BACKGROUND AND QUALIFICATIONS

5. My qualifications are most accurately reflected in my curriculum vitae (EX2024). The following is a brief summary of some of my relevant experience and qualifications.

6. I am the McKnight Presidential Endowed Professor and Distinguished McKnight University Professor in the Department of Computer Science and Engineering of the University of Minnesota in Minneapolis, Minnesota. I am also the Director for the Minnesota Robotics Institute.

7. I have been a professor at the University of Minnesota (originally as an assistant professor, and then as an associate professor) since the Fall 1992. Between Fall 2001 and Spring 2004, and between Fall 2010 and Spring 2013, I was the Director of Undergraduate Studies of the Department of Computer Science and Engineering.

8. In 1992, I received my Ph.D. in Electrical and Computer Engineering from Carnegie Mellon University. My thesis was entitled "Controlled Active Vision" and focused on using computer vision in a controlled fashion to detect, track, and manipulate objects in the environment. In 1988, I also received my M.S. in Electrical and Computer Engineering from Carnegie Mellon University. My

B.S. in Electrical and Computer Engineering was received in 1987 from the National Technical University in Athens, Greece.

9. For over thirty years, my research and teaching work has focused on robotics, image processing, computer vision, and intelligent transportation systems. This research has included a wide variety of topics ranging from drones to detection and tracking of humans and objects such as faces using information from stationary or moving cameras. It has also included object detection and recognition including work with artificial intelligence and pattern recognition systems for surveillance applications.

10. I currently teach or have been teaching three courses related to image processing and computer vision: (i) CSci 5561 Computer Vision, (ii) CSci 5511 Artificial Intelligence, and (iii) CSci 5551 Introduction to Intelligent Robotic Systems. In particular, I have been teaching the class in Computer Vision since 1992.

11. I am currently serving as a Senior Editor in the IEEE Transactions on Intelligent Transportation Systems with responsibility in the area of imaging. I was Associate Editor in the same journal for twelve years.

12. I have received research grants for various projects involving robotics, computer vision and image processing as applied to medicine and surveillance, including face detection and tracking of humans. My industrial experience

includes founding a robotics company in 2005 named ReconRobotics Inc. that develops different robotic platforms. I have also been a consultant since 1997 for numerous companies and provided technical expertise in developing computer vision algorithms for human tracking, object recognition, fingerprint recognition, vehicle tracking, camera calibration, inspection, and precision agriculture.

13. In one of my consulting assignments, I developed computer vision algorithms for inspection of industrial parts by using different illumination sources (Banner Engineering). I have licensed my algorithms to several industries with the most recent one being Sentra Inc., which is using image processing and image segmentation for precision agriculture.

14. My research has produced more than 400 journal and conference publications. More than 90 publications are in refereed journals including top journals in robotics and imaging such as IEEE Trans. on Robotics and Automation, IEEE Trans. on Pattern Analysis and Machine Intelligence, IEEE Trans. on Image Processing, and International Journal of Computer Vision. Many of my publications and research grants relate to drones and human detection and tracking systems.

15. Some examples include:

- Henderson, T., Favour, R., Hamlen, B., Mitha, I., Bowe, E., and Papanikolopoulos, N.P., "Hovering Locomotion for UAVs with Thrust-Vectoring Control Surfaces", IEEE Robotics and Automation Letters, Volume

7, No. 2, April 2022, PP. 5214-5221. The paper was also presented at the 2022 IEEE Int. Conference on Robotics and Automation.

- D'Sa, R., and Papanikolopoulos, N., "Design and Experiments for Multi-Section-Transformable (MIST)-UAV", Proceedings of the 2019 IEEE Int. Conference on Robotics and Automation, Montreal, Canada, May 20-24, 2019, PP. 1878-1883.
- Walczak, N., Fasching, J., Cullen, K., Morellas, V., and Papanikolopoulos, N.P., "Toward Identifying Behavioral Risk Markers for Mental Health Disorders: An Assistive System for Monitoring Children's Movements in a Preschool Classroom," Machine Vision and Applications, Volume 29, No. 4, May 2018, PP. 703-717.
- Andersh, J., Cherian, A., Mettler, B., and Papanikolopoulos, N.P., "A Vision Based Ensemble Approach to Velocity Estimation for Miniature Rotorcraft", Autonomous Robots, Volume 39, No. 2, August 2015, PP. 123-138.
- Cook, D., Morris, T., Morellas, V., and Papanikolopoulos, N., "An Automated System for Persistent Real-Time Truck Parking Detection and Information Dissemination," Proceedings of the 2014 IEEE Int. Conference on Robotics and Automation, Hong Kong, China, May 31 – June 7, 2014, PP. 3989-3994.
- Somasundaram, G., Sivalingam, R., Morellas, V., and Papanikolopoulos, N.P., "Classification and Counting of Composite Objects in Traffic Scenes Using Global and Local Image Analysis", IEEE Trans. on Intelligent Transportation Systems, Volume 14, No. 1, March 2013, PP. 69-81.
- Masoud, O., and Papanikolopoulos, N.P., "A Novel Method for Tracking and Counting Pedestrians in Real-time Using a Single Camera," IEEE Trans. on Vehicular Technology, Volume 50, No. 5, September 2001, PP. 1267-1278.

- Singh, S., and Papanikolopoulos, N. P., “Monitoring Driver Fatigue Using Facial Analysis Techniques,” Proceedings of the 1999 IEEE/IEEJ/JSAI International Conference on Intelligent Transportation Systems, PP. 314- 318, Tokyo, Japan, October 5-8, 1999.

16. My UAV research focused on solar-powered drones capable of flying for multiple days continuously and transformable multi-section UAV designs. My work includes developing the world's smallest solar-powered UAV with applications in precision agriculture for maximizing crop yield, and detecting harmful algae growth in aquatic ecosystems. I have developed the Multi-Section-Transformable (MIST) UAV, a shape-shifting Vertical Take-Off and Landing platform that can transform in-air between multi-rotor, tail-sitter, and fixed-wing configurations. We have applied UAV technology to robot-based precision agriculture, specifically developing high-altitude aerial image analysis systems for weed detection and classification. My research combines robotics, computer vision, and machine learning to create practical UAV solutions for agriculture, environmental monitoring, and transportation systems.

17. My work in vehicle detection and tracking has focused on using image and video processing techniques, including object detection, tracking, and recognition, to accurately track vehicles in real-time. These algorithms have been applied to different scenarios, such as urban traffic monitoring and surveillance.

Moreover, machine learning techniques have helped in the improvement of these methodologies.

18. My paper “Detection and Classification of Vehicles,” published in the IEEE Transactions on Intelligent Transportation Systems in March 2002, is one of the most cited papers in the history of this journal (more than one-thousand citations). The paper, among other contributions, shows how to segment the main object from videos and images in low-light conditions. I also hold nine patents in pertinent areas. One of them is the “Crowd Counting and Monitoring” with P. Kilambi and O. Masoud. It discloses a system and method for accurately estimating the number of people in a crowded area and monitoring their behavior. The invention utilizes computer vision techniques and machine learning algorithms to analyze video feeds from cameras overlooking the target area. It employs techniques such as background subtraction, main object detection, and tracking to identify individual people within the crowd.

19. My research work (individually and with my collaborators) has been funded by several government funding agencies. For example, we have received funding from the Department of Homeland Security to monitor threats at Mass Transit Sites like the 30th Street Station in Philadelphia, PA, and the Light Rail Station in the Minneapolis-Saint Paul International Airport. Tracking humans was

an essential task for which we developed a variety of image processing algorithms and tools.

20. I have received numerous honors and awards for my research and contributions. I have been a Distinguished McKnight University Professor at the University of Minnesota since 2007 and have been a McKnight Presidential Endowed Professor in Computer Science since 2016. Also in 2007, I was nominated and became an IEEE Fellow. In 2016, I received the IEEE RAS George Saridis Leadership Award in Robotics and Automation as well as the Center for Transportation Studies Research Partnership Award. I have also received the IEEE VTS 2001 Best Land Transportation Paper Award for the paper “A Novel Method for Tracking and Counting Pedestrians in Real-Time Using a Single Camera” (with Osama Masoud). Most recently (2025), I was elected to become a Fellow of the National Academy of Inventors.

21. As a result of my work and research, I am familiar with the design, operation, and functionality of unmanned aerial vehicles (UAVs), also known as drones, such as those described in the '711 patent.

III. COMPENSATION

22. I am being compensated as an expert witness in this case at my standard hourly rate in addition to out-of-pocket expenses. I have received no additional compensation for my work on this matter and my compensation does

not depend, and has not ever depended in any way, on my opinion as expressed in this declaration and in any testimony that I may give, or on the outcome of this matter. I have no financial stake in Airspace Systems, Inc., its subsidiaries, parent organizations, or affiliates, the '711 patent, or the outcome of this IPR or any other matter involving the '711 patent.

IV. MATERIALS CONSIDERED

23. In formulating my opinions, I have relied upon my training, knowledge, and experience that are relevant to the '711 patent. I have also considered the '711 patent, patent applications identified in the priority claim of the '711 patent, and its file history. In addition, I have reviewed the Petition ("Pet.") and attached exhibits, including the declaration by Dr. Singhose and the prior art cited by Petitioners. Moreover, I have considered the Patent Owner Preliminary Response (POPR) and attached exhibits, the Board's Institution Decision, Patent Owner Response (POR) and attached exhibits, and substitute claims proposed by Patent Owner. For the sake of convenience and quick reference, I have reproduced above Patent Owner's Exhibit List, listing some of the materials that I considered.

V. LEGAL PRINCIPLES

24. I am not an attorney. I have been asked to provide opinions on patentability of the claims challenged by Petitioners and substitute claims proposed

by Patent Owner. To this end, I relied on certain legal principles that were provided to me by counsel and that are summarized below.

A. Claim Construction

25. I am informed by counsel and understand that “claim construction” is the interpretation of the meaning of patent claims. I understand that words of a claim are generally given their ordinary and customary meaning, which is the meaning the term or phrase would have to a person of ordinary skill in the art (POSITA) at the time of the invention. I understand that both intrinsic and extrinsic evidence can be used to assist in understanding the meaning of a claim. Intrinsic evidence includes the claim language, language in other claims of the patent, the specification, and the prosecution history.

26. I further understand that, unless required by the claim language or specification, claims should generally not be limited to embodiments in the specification, including preferred embodiments. I understand that extrinsic evidence, which consists of all evidence external to the patent and prosecution history including expert and inventor testimony, dictionaries, and learned treatises, may also be relevant to claim construction.

B. Invalidity Based on Prior Art

27. I am informed and understand that each claim of an issued patent is presumed to be valid. In an IPR proceeding, a party challenging the validity of a

patent claim, whether an issued claim or a proposed substitute claim, must present a preponderance of the evidence to demonstrate invalidity of that claim.

1. Prior Art

28. I am informed by counsel and understand that in an IPR proceeding, a Petitioner can only rely upon a patent or other publication as prior art. I also understand that a particular patent may claim priority to one or more earlier filed patent applications, and that subject to meeting certain conditions, the effective filing date of that particular patent can be the actual filing date of the earliest patent application in the priority claim of that particular patent. I am also informed and understand that the earliest priority date of a patent is the effective filing date of that patent.¹

29. I understand further that with respect to a challenged patent, a U.S. or foreign patent may qualify as prior art if the date of issuance of the patent is prior to the effective filing date of the challenged patent. A particular U.S. patent that issued after the effective filing date of a challenged patent may qualify as prior art to the challenged patent if the effective filing date of that particular patent is earlier than the effective filing date of the challenged patent.

¹ I am informed that in certain cases, if the effective filing date is earlier than March 16, 2013, the earliest priority date of that patent may be the date of invention of the claimed invention of that patent.

30. I also understand that a printed publication, such as an article published in a magazine, academic journal, conference proceedings, or trade publication, or U.S. or foreign published patent application qualifies as prior art to a challenged patent if the date of publication of that printed publication is prior to the effective filing date of the challenged patent. Additionally, I am informed and understand that to qualify as prior art, a reference, whether a patent, published patent application, or another printed publication, must contain an enabling disclosure that allows one of ordinary skill to practice the claims without undue experimentation.

2. Anticipation

31. I understand that, once a claim of a challenged patent has been properly construed, the next step in determining whether that claim is anticipated by a prior art reference under 35 U.S.C. § 102 requires a comparison of the properly construed claim language to the prior art reference on a limitation-by-limitation basis.

32. I understand that a prior art reference “anticipates” a challenged claim, and therefore renders the claim invalid, if all elements of the claim are disclosed in that prior art reference, either expressly or inherently (i.e., necessarily present), arranged in the same way as in the claim. I understand that, for inherent

anticipation, it is required that the missing descriptive material is necessarily present in the prior art reference, and not merely probable.

33. I also understand that to anticipate a challenged claim, an allegedly anticipatory prior art reference must provide a disclosure that enables the challenged claim. I understand an enabling disclosure describes the invention of the challenged claim in sufficient detail that would allow a POSITA to make and use that invention without undue experimentation.

34. I understand that for the purposes of an IPR proceeding, a patent claim is anticipated if there is proof that, more than one year before the priority date of that claim, the claimed invention was: patented anywhere in the world or described in a printed publication anywhere in the world. This I am informed is called a statutory bar.

35. I have written this declaration with the understanding that, in an IPR, anticipation must be shown by a preponderance of the evidence. I understand that a preponderance of the evidence means that it is more likely than not that the prior art reference discloses all of the elements of a challenged claim.

3. Obviousness

36. I informed by counsel and understand that even if a challenged claim is not anticipated, it may still be invalid pursuant to 35 U.S.C. § 103 as obvious, if the differences between the claimed subject matter and the prior art are such that

the subject matter as a whole would have been obvious at the time the invention was made to a POSITA.

37. I understand that a POSITA provides a reference point from which the prior art and claimed invention should be viewed. This reference point prevents one from using his or her own insight or hindsight in deciding whether a claim is obvious. I also understand that an obviousness determination includes the consideration of various factors such as (1) the scope and content of the prior art, (2) the differences between the prior art and the challenged claim, (3) the level of ordinary skill in the pertinent art, and (4) the existence of secondary considerations (also called objective indicia of non-obviousness).

38. I am further informed by counsel and understand that a claim is not proved obvious merely by demonstrating that each of the elements was independently known in the prior art. I understand that many inventions rely on known building blocks, and that claimed inventions, often of necessity, can be combinations of what was already known. I understand that it is therefore important to identify whether a reason existed at the time of the invention that would have prompted a POSITA to combine such known elements in the way the claimed invention does. Such reasons are typically described as the motivation to combine two or more prior art references.

39. I understand that an obviousness evaluation can be based on a combination of several prior art references. I understand that the prior art references themselves may sometimes provide a suggestion, motivation, or reason to combine, but at other times the nexus linking two or more prior art references can be based on the ordinary understandings available to a POSITA. I further understand that obviousness analysis recognizes that market demand, rather than scientific literature, often drives innovation, and that a motivation to combine references may be supplied by the direction of the marketplace.

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

41. I further understand that secondary considerations of non-obviousness (also known as objective indicia of non-obviousness) may include: (1) a long felt but unsolved need; (2) commercial success; (3) unexpected results; (4) industry praise; (5) licensing; and (6) copying by others. I also understand that there must be a relationship or nexus between any such secondary considerations and the

claimed invention. Where the offered secondary consideration results from something other than what is both claimed and novel in a challenged claim, there is no nexus to the merits of the claimed invention.

42. I understand that a nexus is presumed where the secondary considerations are tied to a particular product which: (i) embodies the claimed invention and (ii) is coextensive with the claimed invention. In analyzing whether a product is coextensive with the claimed invention, I understand that there is no requirement for a perfect correspondence between the claims and the product, and that the presumption of a nexus can still apply when unclaimed features present in the product amount to nothing more than additional insignificant features.

43. I further understand that Patent Owner bears the burden of demonstrating that the relevant secondary indicia are attributable to the claimed invention, as opposed to other economic and commercial factors unrelated to the technical quality of the patented subject matter. I also understand that contemporaneous and independent invention by others is a secondary consideration supporting an obviousness determination. Additionally, I understand that, as a safeguard against hindsight bias, all secondary considerations of non-obviousness must be considered prior to reaching an obviousness conclusion.

44. It is further my understanding, as informed by counsel, that a proper obviousness analysis focuses on what was known or obvious to a POSITA, not just

Patent Owner. Accordingly, I understand that any need or problem known in the field of endeavor at the time of invention and addressed by the challenged patent can provide a reason for combining the elements in the manner claimed.

45. I understand that whether a prior art reference “teaches away” from the claimed invention is a fact to be considered in determining obviousness. I understand that it is improper to combine references where the references teach away from their combination. I understand, however, that the nature of the teaching is highly relevant and must be weighed in substance; a challenged claim may be obvious over a combination of prior art teachings even if one of those teachings has been described as somewhat inferior to some other teachings. Furthermore, I understand that the prior art’s mere disclosure of more than one alternative does not constitute a teaching away from a particular alternative when such disclosure does not criticize, discredit, or otherwise discourage the use of that alternative.

46. I understand that, in an IPR proceeding, obviousness must be proven by a preponderance of the evidence such that a POSITA at the time of the alleged invention would have had a reason (or reasons) for combining the teachings of those prior art references to achieve the claimed invention, and that the POSITA would have had a reasonable expectation of success of achieving the claimed invention by combining those teachings.

4. Proposed Substitute Claims

47. I am informed by counsel and understand that in a motion to amend, Patent Owner may cancel any challenged claim or propose a reasonable number of proposed substitute claims for each challenged claim. 35 U.S.C. § 316(d)(1). I am also informed by counsel and understand that there is a rebuttable presumption that a reasonable number of proposed substitute claims per challenged claim is one. 37 C.F.R. § 42.121(a)(3).

48. I am also informed by counsel and understand that per the applicable rules, a motion to amend may be denied if it does not respond to a ground of unpatentability involved in the trial. 37 C.F.R. § 42.121(a)(3). I am further informed and understand that the “rule does not require ... that every word added to or removed from a claim in a motion to amend be solely for the purpose of overcoming an instituted ground,” and that additional modifications may be included. *Lectrosonics, Inc. v. Zaxcom, Inc.*, IPR2018-01129, Paper 15 (Information and Guidance on Motions to Amend) at 5-6.

49. Additionally, I am informed by counsel and understand that no proposed substitute claim may enlarge the scope of the claims of the challenged patent. 35 U.S.C. § 316(d)(3); 37 C.F.R. § 42.121(a)(2)(ii). Finally, I am informed by counsel and understand that no proposed substitute claim may introduce new subject matter. 35 U.S.C. § 316(d)(3); 37 C.F.R. § 42.121(a)(2)(ii).

VI. LEVEL OF ORDINARY SKILL IN THE ART

50. My opinions herein are based from my standpoint of a POSITA at the time of invention of the '711 patent.

51. In my opinion, for the purposes of this IPR proceeding, the '711 patent is entitled to a priority date of at least September 26, 2018, the filing date of U.S. Pat. App. No. 16/142,452 (the "'452 App.") from which the '711 patent issued. EX1001 (face page). The '711 patent claims priority to U.S. Pat. App. No. 15/729,581 (filed on October 10, 2017), and to U.S. Provisional Pat. App. Nos. 62/566,449 (filed on October 1, 2017) and 62/405,972 (filed on October 9, 2016). One or more challenged claims of the '711 patent and one or more proposed substitute claims may be entitled to claim priority to the filing date of a patent application in the priority claim of the '711 patent. My opinions herein would not change in that case.

52. I understand that Petitioners and their expert Dr. Singhose have stated that a POSITA would have had "either (1) at least a Bachelor of Science in Mechanical Engineering, Electrical Engineering, Aerospace engineering, or an equivalent field, as well as at least 2 years of academic or industry experience in the aerospace or avionics fields, or (2) at least four years of experience in any of the above industries." Pet. at 8; Ex. 1003 ¶ 50-53.

53. I disagree. As I discuss below, the UAVs disclosed and claimed in the '711 patent employ machine learning / neural networks in order to solve problems pertaining to autonomous flight. Therefore, in my opinion, one can be considered as having ordinary skill in the field of the '711 patent only if such a person were adequately trained and/or had industrial experience in computer science, and specifically in artificial intelligence / machine learning. Therefore, in my opinion, a POSITA would have had either: (1)(a) at least a bachelor of science in mechanical engineering, electrical engineering, aerospace engineering, or an equivalent field, or (b) at least four years of experience in any of the above disciplines, and (2)(a) at least a bachelor's degree in computer science, or (b) at least four years of experience in the software industry in the field of artificial intelligence / machine learning.

54. None of my opinions herein would change if the Board adopts Petitioners' definition of the level of skill in the art were adopted instead. Under either Party's proposed definition of the level of ordinary skill in the art, at the relevant time frame, I was a person of more than ordinary skill in the art. I also worked with and managed many people who fit the characteristics of a POSITA (as proposed by either party), and I am familiar with their level of skill.

VII. SUMMARY OF MY OPINIONS

55. Petitioners have challenged claims 1-20 of U.S. Patent No. 10,514,711 (the “’711 Patent”) on 22 Grounds. The invention claimed in the ’711 Patent enable an unmanned aerial vehicle (UAV) to autonomously perform flight control operations based on the relative location of an airborne target such as another UAV, without human guidance, and without being controlled by a ground-based navigation system. As I further explain below, “autonomous” navigation by a UAV is different navigation from the one according to autopilot commands received from the ground. As such, the prior art cited in the two Grounds that challenge claim 12 does not teach or suggest “autonomously navigating” that claim 12 recites. Therefore, as further discussed below, in my opinion claim 12 is patentable.

56. Regarding the proposed substitute claims 21-40, I explain below that these claims are fully supported by the specification of the ’711 patent, and as such, no new matter is introduced. These proposed substitute claims narrow the respective scopes of challenged claims 1, 4, 19, and 20 by adding respective further limitations. The further limitations distinguish the proposed substitute claims from the cited prior art, individually or in combination with other cited prior art, and are therefore responsive to the Grounds under which claims 1, 4, 19, and

20 are challenged. For these reasons, the proposed substitute claims are also patentable.

57. In particular, to facilitate autonomous flight control operations, the UAV of the '711 patent detects the airborne target, and continues with the detection, e.g., while avoiding or pursuing the target. The UAVs described in the '711 patent perform such detection at the UAV using an on-board neural network / machine learning (ML) model. None of the prior are cited by Petitioners, individually or in combination with other cited prior art, discloses or suggests implementation of a neural network / ML model at a UAV for target detection. Proposed substitute claim 21, *inter alia*, recites “detecting at the reference aerial vehicle a target in the image by applying at the reference aerial vehicle a machine learning model.” Therefore, in my opinion, proposed substitute claim 21 is patentable. Proposed substitute claim 24 depends from proposed substitute claim 21 and is patentable at least for that reason.

58. The '711 patent also discloses that the detection of a target, which includes continuing detection, can be performed using a neural network and incremental prediction, or using two (or more) different neural networks / ML models. The '711 patent also discloses the benefits of using such different techniques, and additionally discloses a mechanism for switching between two different techniques. As discussed below, proposed substitute claims 39 and 40 are

directed to the above described features, which none of the cited prior art, individually or in combination with other cited prior art, teaches or suggests. Therefore, it is my opinion that proposed substitute claims 39 and 40 are also patentable.

VIII. THE '711 PATENT

A. Administrative Overview

59. I have reviewed and agree with the administrative overview of the '711 patent that Patent Owner provided in the Patent Owner's Preliminary Response (POPR). Therefore, I reproduce that administrative overview herein.

60. The '711 Patent issued from U.S. Patent Application No. 16/142,452 (the '452 App."), that was filed on September 26, 2018. EX1001, face page. The '452 App. is a continuation-in-part of U.S. Patent Application No. 15/729,581 (the '581 Application), filed on October 10, 2017. The '452 App. also claims priority to U.S. Provisional Patent Application No. 62/566,449, filed on October 1, 2017, and to U.S. Provisional Patent Application No. 62/405,972, filed on October 9, 2016. See EX1001, 1:7-23; Paper 11 at 4.

B. Prosecution History

61. I have reviewed and agree with the prosecution history of the '711 patent that Patent Owner provided in the POPR. Therefore, I reproduce that prosecution history herein.

62. During the prosecution of the '452 App., in the first Non-Final Office Action mailed on November 23, 2018, claims 1-11, 14, 19, and 20 were rejected under 35 U.S.C. § 103 over several prior art references. Claims 12, 13, and 15-18 were indicated as reciting allowable subject matter. *See* EX1002 at 104-115. In a response filed on February 20, 2019, Applicant amended various claims, including claim 1. *See id.* at 158-163; Paper 11 at 4.

63. A Final Office Action was mailed on March 12, 2019, in which claims 1-11, 14, 17, 19, and 20 were rejected under 35 U.S.C. § 103 over some previously cited and some new prior art references. Claims 12, 13, and 15, 16, 18 were indicated as reciting allowable subject matter. *See* EX1002 at 165-177. In a response filed on July 11, 2019, Applicant incorporated the subject matter recited in original claim 12, that was indicated as allowable, into independent claims 1, 19, and 20. *See id.* at 215-221; Paper 11 at 5.

64. The Notice of Allowance issued thereafter on August 2, 2019. *See* EX1002 at 222-229. In the reasons for allowance, the Examiner stated that the limitations recited in original claim 12, now incorporated into claims 1, 19, and 20, were not taught or suggested by the prior art of the record. *See id.* at 227. These limitations include, *inter alia*, “determining a speed adjustment factor based on a magnitude of deviation of a direction of the three-dimensional relative location

with respect to a current flight direction of the reference aerial vehicle.” *See id.*; Paper 11 at 5.

C. Subject Matter

65. I have reviewed and agree with the discussion of the subject matter of the ’711 patent that Patent Owner provided in the POPR. Therefore, I reproduce that discussion of the subject matter herein. In addition, to certain innovative features of the ’711 patent, and their benefits, that are reproduced below, I also discuss the need for and the advantages of performing object detection within the images captured by a UAV using a neural network / ML model. Moreover, I discuss certain challenges associated with the use of this technique, and how the ’711 patent overcame these challenges by using not only one but two or more different neural networks / ML models.

66. The ’711 patent discloses and claims techniques for “performing a flight control operation of a reference aerial vehicle” based on the three dimensional (3D) relative location of a target that it detects using machine learning. *See* EX1001, Abstract, 31:10-33:2. In particular, the ’711 patent notes that as the use of UAVs, also known as drones, would proliferate, some UAVs may be “used to carry contraband,” “to perform unauthorized surveillance,” and even to commit acts of terrorism. *See id.*, 3:3-11. To mitigate such risks by malicious UAVs, the ’711 patent explains, that it may be necessary to deploy an interceptor

UAV to interdict a malicious UAV (i.e., a target), e.g., “intercept, capture, and transport away a UAV that has entered a restricted area.” *Id.*, 3:11-21.

67. Typically, however, because such interceptor UAVs were controlled by human flight controllers, a number of problems arose when attempting to have the UAV intercept a target. First, the human had to “have a visual sight” of the target to capture it. *Id.*, 1:27-31. Second, “challenges arose in circumstances where a trained human user is unavailable or unable to react quickly enough to perform a desired flight maneuver.” Additionally, “if **communication between the [interceptor UAV] and the flight controller is lost or becomes unreliable**, the [interceptor UAV] may be unable to perform a desired flight operation.” *Id.*, 1:31-36. An additional challenge is manually controlling a UAV when the target, such as another UAV, is also moving. *See id.*, 3:21-25. For these reasons, the Patent explains “it may not be desirable to manually control the interceptor [UAV.]” *Id.*, 3:25-26.

68. Patent Owner not only recognized this critical problem, but also devised an innovative and multi-faceted solution—an “interceptor aerial vehicle [that] is able to **autonomously** track and fly to the target UAV using machine vision based on images captured by a camera of the interceptor aerial vehicle.” *Id.* 3:27-30. Patent Owner not only conceived and patented this solution; it also built

an embodiment of this invention that it supplied to the United States Army in 2018, as a first-of-its-kind, fully autonomous interceptor UAV.

69. To build this revolutionary autonomous interceptor UAV, Patent Owner entered into an agreement with the U.S. Army under which it received over \$3.5 million in funding from the U.S. Army’s “Defense Innovation Unit – Experimental (DIUs) Commercial Solutions Offering (CSO).” EX2001, Article 1, § A. This agreement described Patent Owner’s technology as “**cutting edge** counter unmanned aerial system (cUAS) robotic ‘interceptor drone.’” *Id.* The Airspace UAV was accepted for inclusion in the Smithsonian National Air and Space Museum’s collection of historically significant aircraft in March 2024. EX2002.

70. Patent Owner’s innovative and multi-faceted solution, as disclosed and claimed in the ’711 patent and as embodied in the UAV interceptor delivered to the US Army and accepted into the Smithsonian’s collection, has a number of important features. The first one is the **machine-learning based detection** of a target from the images captured by a UAV used for interdiction, referred to in the ’711 patent as the “reference UAV.” *See* EX1001, 17:25-27; *see also, id.*, 13:26-35, FIG. 3A. Machine-learning based detection of an object/target is not limited to mere object/target classification. *See* EX2003 at 1212, col. 2; EX2004 at 1. Machine-learning based detection, according to the ’711 patent, comprises

determining that a target is present in the captured image and identifying that target, e.g., by placing a bounding box around the target. *See* EX1001, 17:25-38. The '711 patent's machine-learning based target detection additionally includes detecting or identifying one or more features of a target, e.g., the "type, model, class, manufacturer, size, etc. of the detected target." *See id.*, 17:31-38.

71. The operating environment of a UAV tends to be noisy due to many factors such as vibrations from rotors, minimal use of damping materials supporting the on-board cameras (to minimize the UAVs weight), air flow affecting the UAV which can change from time-to-time and cause bumpy movement, and sudden direction and/or speed changes in the UAV movement in a three-dimensional space. Due to these factors, the images captured by a camera on-board a UAV can be of significantly poorer quality, compared to those captured by a stationary or even a human-held camera. As such, conventional image-processing techniques used for object detection in such UAV-captured images can be inaccurate and/or too slow due to extra computations to suppress the noise. *See, e.g.*, EX2022; EX2023.

72. The advent of artificial intelligence / machine learning addressed the above-described problem, but only in part. First, before the invention of the '711 patent, UAVs for tracking ground-based objects were known. *See, e.g.*, EX1009, 1:46-62, FIG. 1; EX1005, ¶ 18, FIG. 1. As such, to the extent these UAVs relied

on a neural network / ML based object detection, those neural networks / ML models were typically trained using ground-based targets. The potential targets of a UAV, whether to be avoided or pursued, are also airborne like the UAV and may appear and move unpredictably in the three-dimensional space. The '711 patent disclosed training ML models to detect such airborne objects. *See id.* 8:48-57.

73. Second, an implementation of a machine learning model, such as a neural network, or another system, tends to be “costly,” i.e., computationally expensive, e.g., in terms of the requirements of processor load / processing cycles (which related to the processing time), memory consumption, and/or energy and/or power consumption. Therefore, analysis of images using neural networks / ML models is typically performed at a ground based server having large processing and memory capacity. When the images are captured by a camera on-board a UAV, the captured images can be transmitted to a ground-based server, and information about the detected target(s) can be received from the ground-based server.

74. The inventors of the '711 patent recognized a problem with this solution, however. In many situations, communication between a UAV and a ground station can be unavailable or unreliable. *See EX1001*, 1:34-37. For example, the communication may be entirely unavailable if the UAV is flying over a remote / foreign region, and it may be intermittent in an urban area, e.g., due to interference. The inventors solved this problem by performing neural network /

ML based target detection on-board. *See id.* 3:31-36, 7:27-32, 9:52-64, 13:26-37, 16:37-41, FIGS. 2, 3A-B. One way in which the inventors of the '711 patent mitigated the excessive computing cost of a neural network / ML model was to perform the image analysis on tiles (subsets) of a frame and not necessarily on the entire frame. *See id.* 28:40-47.

75. Even when a neural network / ML model is applied only to a tile (portion of an image frame) the computation cost, e.g., in terms of the processing time, can still be high. As such, another way in which the inventors mitigated the computation cost was not to employ a single neural network / ML model, but to selectively use two or more neural networks / ML models of different kinds for on-board object detection. *See id.* 27:43-28:18.

76. Generally, prior to the initial detection of a target, it is not known whether a target would be detected. Even if a target is present in the captured image, it is not known initially where in the captured image the target would be detected. Moreover, depending on the target's physical size and distance thereto, it is generally not known how big the target would appear in a captured image. As such, the '711 patent teaches that a neural network / ML model that processes high-resolution images may be used initially to detect the target. *See id.* Such a neural network / ML model may detect a target accurately, but the neural network / ML model's cost may be high, i.e., it may require significant processing capacity, and

as such, significant processing time. As such, the refresh rate of such a neural network / ML model, i.e., the rate at which new images can be accepted and processed, may be low. *See id.*

77. Once a target is detected, however, certain information about the target, such as the target's relative size in the captured image and its direction relative to the UAV heading, becomes known. Although both the UAV and the target are moving in a three-dimensional space, using the available information about the target, it can be predicted with some probability where the target would likely appear in the subsequently captured images. *See id.* As such, the '711 patent teaches that a different neural network / ML model that processes medium or low resolution images may be used for continuing the detection of the target subsequent to the initial detection. *See id.*

78. The computational cost of such a neural network / ML model may be medium or low and it may require relatively less processing capacity and time. As such, the refresh rate of such a neural network / ML model can be relatively high. *See id.* The ability to capture and process new images can be highly beneficial if the target is rapidly moving away from the UAV. Of course, it is possible that the UAV may lose track of the detected target, in which case, the '711 patent teaches that it may become necessary to switch back to the high-resolution, high-cost neural network / ML model. *See id.*

79. Another important feature of the '711 patent concerns the determination/estimation of the three-dimensional relative location of the target with respect to the interceptor ("reference UAV"), including the distance between the reference UAV and the target and the direction of the target. *See id.*, 17:39-49, 18:12-49, FIG. 5. The '711 patent teaches performing such distance estimation by comparing the size of the target within the captured image to the size of the image, because a "target that is further away will appear smaller in the image as compared to the target that is closer and thus the size of the target within the image can be used as a proxy for distance to the target." *Id.*, 17:42-49.

80. A significant challenge is presented, however, when the actual target size is not known *a priori*. This is likely the case when the target is another UAV, because UAVs can vary in shapes and sizes significantly. *See id.* 17:49-53. To address this problem, the '711 patent teaches using a "machine learning model [on-board that] has been **trained using different examples of types of aerial vehicles** (e.g., different models, types, manufacturers, sizes, etc.) to be able to classify and **identify the specific type of the detected target aerial vehicle** and a corresponding size profile corresponding to the specific type." *Id.*, 17:53-58. Then, "a measurement of the target within the image," e.g., one or more size parameters of a bounding box associated with the target, "can be mapped to a

distance value based on a determined size corresponding to the detected type/classification of the target.” *Id.*, 17:61-67.

81. Yet another important feature of the ’711 patent pertains to its automated navigation. As I noted earlier, in many situations, communication between a UAV and a ground station can be unavailable or unreliable. The inventors of ’711 patent recognized that in such situations, “the aerial vehicle may be unable to complete a desired flight operation.” *Id.* 1:34-37. To address this problem, the UAV of the ’711 patent does not rely on receiving flight control instructions from a ground station. Rather, the UAV can operate **autonomously**, i.e., it can **self-determine** the speed, elevation, flight-path, etc., based on the relative location of the target that the UAV determined.

82. To this end, the ’711 patent discloses a UAV 301 having a CPU “configured to control the overall operation of UAV 301.” *Id.* 9:25-27. The “CPU may be configured to perform one or more **flight decisions** for the UAV” by providing “one or more flight commands” that “may include a specified speed for the UAV, a specified flight height for the UAV, a particular flight path for the UAV, etc.” *Id.* 9:38-43, 16:49-55 (when a target is detected, “a flight direction and/or speed of an interceptor aerial vehicle are automatically and autonomously adjusted”), FIGS. 3, 4.

83. A unique aspect of the speed adjustment described and claimed in the '711 patent is that the speed is not adjusted solely based on how far the target is, *see id.*, 18:54-59, but is based on the magnitude of directional deviation of the target relative to the current heading of the reference UAV. *See id.*, 19:4-8, 19:14-20.

IX. CLAIM CONSTRUCTION

84. I am informed by counsel and understand that in an *inter-partes* review proceeding, as in a Federal Court, the claims are interpreted according to the *Phillips v. AWH Corp.*, 415 F.3d 1303 (Fed. Cir. 2005) (*en banc*) standard. In other words, I am informed and understand, that the claim terms are interpreted according to their “ordinary and customary meaning” also referred to as the plain and ordinary meaning. I have adopted this standard in my analysis of both the issued claims and the proposed substitute claims.

85. I understand that the POPR presented respective constructions of certain claim terms of claims 1, 19, 10 based on Patent Owner’s understanding of the plain and ordinary meaning of those claim terms. *See* Paper 16 at 7-11. I further understand that the Board did not adopt Patent Owner’s claim constructions. *See id.* at 10-11.

86. I note further that claim 12 recites “autonomously navigating the reference aerial vehicle.” The '711 patent discloses a UAV 301 having a CPU

“configured to control the overall operation of UAV 301.” *Id.* 9:25-27. The “CPU may be configured to perform one or more **flight decisions** for the UAV” by providing “one or more flight commands” that “may include a specified speed for the UAV, a specified flight height for the UAV, a particular flight path for the UAV, etc.” *Id.* 9:38-43, 9:49-51 (in some “embodiments, the **CPU is configured to autonomously fly UAV 301**”), 16:49-55 (when a target is detected, “a flight direction and/or speed of an interceptor aerial vehicle are automatically and autonomously adjusted”), FIGS. 3, 4.

87. Therefore, it is my opinion that in light of the specification of the ’711 patent, the plain and ordinary / customary” meaning of “autonomously navigating” is making navigation decisions by-itself without outside control.² *See* EX2011 (defining “autonomous” as “undertaken or carried on **without outside control**”); EX2012 (defining autonomous as “independent and having the power to **make your own decisions**”).

² I note that the POPR presented not the same but a similar meaning. Paper 11 at 30 (“the plain, ordinary, and customary meaning of ‘autonomously navigating’ is performing navigation by the reference UAV itself”). It is my understanding that in the Institution Decision, the Board did not issue its findings with respect to this claim term recited in claim 12. *See* Paper 16 at 22.

X. EACH OF GROUNDS 1, 9, 10, 17, AND 18 FAILS TO DEMONSTRATE UNPATENTABILITY OF CLAIM 12 BY A PREPONDERANCE OF THE EVIDENCE

A. Ground 1

1. A POSITA Would Not Combine Beard and Laufer to Achieve Autonomous Navigation

88. Claim 12 depends from claim 1 and recites “receiving a geographical location associated with the target detected at least in part using a ground-based sensor;” and further recites “autonomously navigating the reference aerial vehicle towards the received geographical location; and determining to allow image-based navigation.” EX1001, 32:1-7. In Ground 1, Petitioner argues that in the Beard-Laufer combination, Laufer (EX1010) teaches the “autonomously navigating the reference aerial vehicle” limitation. *See* Pet. at 34; EX1003, ¶ 138.

89. I understand that in its Preliminary Response, Patent Owner presented several reasons for which a POSITA would not combine Beard and Laufer. *See* Paper 11 at 18-24. Board considered several of Patent Owner’s arguments pertaining to the limitations recited in independent claims 1, 19, and 20, and did not find those arguments persuasive. *See* Paper 16 at 17-21. I explain below, however, that a POSITA would not have combined Beard and Laufer **to achieve autonomous navigation** of an aerial vehicle.

90. Recall, in Claim Construction, I explained that the proper meaning of “autonomously navigating the reference aerial vehicle” is making navigation

decisions by the reference aerial vehicle by-itself, without outside control. *See supra* § IX.

91. Laufer discloses an “interdiction system 100” that includes a “central controller 115.” EX1010, ¶ 22, FIG. 1. As seen in FIG. 1, the central controller 115 is not on-board a UAV, such as UAVs 122A-C, 124A-C, 140A-B depicted in FIG. 1. In fact, Laufer states that in some embodiments, the “central controller 115 is connected to stationary components of interdiction system 100 by a **wired connection**, for example 10/100 and Gigabit Ethernet connections.” *Id.* ¶ 30. Laufer further states that the “[c]entral controller 115 can be connected to interceptor aircraft 140A-140B through a wireless connection.” *Id.* ¶ 30. A central controller that can have a “wired connection” to certain stationary components and a wireless connection to a UAV is not and cannot be on-board a UAV. Thus, the central controller 115 is not a part of a UAV disclosed by Laufer.

92. Laufer also states that central controller 115 can “determine the location at which ... the target and the interceptor aircraft will intersect,” i.e., the “interception location 425.” *Id.* ¶ 39. Thereafter:

Central controller 115 uses autopilot command module 440 to **generate autopilot aircraft commands 445** based on interception location 425 and the interceptor air craft dynamics model. Central controller 115 uses autopilot command module 440 to solve for the set

of autopilot aircraft commands 445 to cause the interceptor aircraft to fly to interception location 425.

Id. ¶ 40.

93. Thus, in Laufer’s system, navigation of the UAV, so that it may fly to the interception location, is accomplished under the control of the central controller. Laufer’s autopilot commands may not be provided by a human, and may instead be generated by a computer, such as one provided in Laufer’s autopilot command module. But, those autopilot commands are generated by the central controller and not by UAV. Thus, Laufer’s UAV does not navigate itself. Accordingly, Laufer does not teach or suggest “autonomously navigating the reference aerial vehicle,” as claim 12 recites.

94. Moreover, **Laufer’s central controller** having wired connections to stationary components, such as “Doppler radars” and “fixed cameras,” *see id.*, ¶ 29, must be ground based and **cannot be located aboard a UAV**. Therefore, to a POSITA Laufer describes the very sort of conventional interceptor UAV operation that the ‘711 inventors had in mind as being inoperable “if communication between the [interceptor UAV] and the flight controller is lost or becomes unreliable.” EX1001, 1:31-35. The Beard-Laufer combination does not solve this problem, because it sends navigation instructions to a UAV from a ground-based central controller. Therefore, a POSITA **would not have expected this combination to**

be able to provide autonomous navigation for a UAV. As such, in my opinion, a POSITA would not have combined Beard and Laufer to achieve autonomous navigation of a reference aerial vehicle.

2. Claim 12

95. For claim 12, in Ground 1, Beard does not teach, and Petitioners do not allege that Beard teaches, “autonomously navigating the reference aerial vehicle.” *See* Pet. at 34; EX1003, ¶ 138. Even if Laufer is combined with Beard, Laufer also does not teach or suggest this limitation, and to the contrary, teaches only the known, conventional, ground-control based navigation.

96. This is because, as I discuss above, Laufer’s “[c]entral controller 115” provides “autopilot aircraft commands 445 to cause the interceptor aircraft to fly to interception location 425.” EX1010 ¶ 40. But as I also explained above, Laufer’s central controller having **wired connections to stationary components**, such as “Doppler radars” and “fixed cameras,” and a wireless connection to interceptor aerial vehicle, *see id.*, ¶¶ 29, 30, must be ground based and **cannot be located aboard a UAV**. Therefore, Laufer also does not teach or suggest “autonomously navigating the reference aerial vehicle,” as claim 12 recites. Therefore, the Beard-Laufer combination does not teach all of the limitation of claim 12.

B. Grounds 9 and 10

97. Petitioners allege that the combination of Pierce and Laufer in Ground 9 and Pierce, Kumar, and Laufer in Ground 10 renders claim 12 obvious. As in Ground 1, in Grounds 9 and 10 also Petitioners rely only on Laufer as allegedly teaching the “autonomously navigating the reference aerial vehicle” limitation of claim 12. Pierce and Kumar, individually and in combination, do not teach this limitation. Petitioners do not allege otherwise. *See* Pet. at 71; EX1003, ¶ 224.

98. Here again, because Laufer’s central controller that provides the autopilot command to an aerial vehicle is ground based, and cannot be located on the aerial vehicle, a POSITA would not have expected the combinations proffered in these grounds to achieve autonomous navigation of the reference aerial vehicle. Therefore, a POSITA would not have combined Laufer with Pierce or with Pierce and Kumar.

99. Moreover, for the same reasons discussed above for Ground 1, even in the proffered combinations, Laufer fails to cure what Pierce and Kumar lack, because Laufer also does not teach navigation by the reference aerial vehicle by-itself, i.e., “autonomously navigating the reference aerial vehicle,” as claim 12 recites. Therefore, the Pierce-Laufer and Pierce-Kumar-Laufer combinations do not teach all of the limitation of claim 12.

C. Grounds 17 and 18

100. As in Ground 1, in Grounds 9 and 10 also Petitioners rely on Laufer as allegedly teaching the “autonomously navigating the reference aerial vehicle” limitation of claim 12. Pierce, Kumar, and Sahasrabudhe, individually and in combination, do not teach this limitation. Petitioners do not allege otherwise. *See* Pet. at 80; EX1003, ¶¶ 245-247. Therefore, for the reasons provided in connection with Grounds 1, 9, and 10, a POSITA would not be motivated to combine Laufer with Pierce, Kumar, and Sahasrabudhe as suggested by Petitioners.

101. Furthermore, even in the suggested combinations, Laufer does not cure what Pierce, Kumar, and Sahasrabudhe fail to teach or suggest, because Laufer also does not teach navigation by the reference aerial vehicle by-itself, i.e., “autonomously navigating the reference aerial vehicle,” as claim 12 recites. Therefore, the Pierce-Sahasrabudhe-Laufer and Pierce-Kumar-Sahasrabudhe-Laufer combinations also do not teach all of the limitation of claim 12.

102. Accordingly, in my opinion, claim 12 is patentable.

XI. PROPOSED SUBSTITUTE CLAIMS COMPLY WITH LAWS AND REGULATIONS PERTAINING TO A MOTION TO AMEND

A. Patent Owner Has Proposed a Reasonable Number of Proposed substitute claims

103. In the motion to amend, for each of the challenged claims 1-4 and 8-20, Patent Owner has proposed only a single corresponding proposed substitute claim. I believe this is a reasonable number of proposed substitute claims.

B. Each Proposed substitute claim Responds to a Ground of Unpatentability

104. Each proposed substitute claim retains all of the limitations of the limitations of the corresponding challenged claim. Proposed independent substitute claims 21, 36, and 37, and proposed substitute claim 24 each adds further limitations. As I explain below, none of the prior art cited under any of Petitioners' 22 Grounds teaches or suggests, individually or in combination with other cited prior art, one or more of these **further limitations**. *See infra* § XII. All of the proposed dependent substitute claims depend from proposed substitute independent claim 21. Therefore, in my opinion, the proposed substitute claims respond to one or more Grounds of unpatentability.

C. No Proposed Substitute Claim Enlarges the Scope of the Claims of the '711 Patent

105. As stated above, each proposed substitute claim retains all of the limitations of the corresponding challenged claim. Proposed independent

substitute claims 21, 36, 37 and proposed substitute claim 24 each is amended to recite further limitations. In proposed substitute claims 22, 23, and 25-35, only the dependencies are amended. As such, in my opinion, no proposed substitute claim enlarges the scope of the claims of the '711 patent.

D. No Proposed substitute claim Introduces New Subject Matter and Is Fully Supported by the Original Disclosure of the '711 Patent

106. I discuss below that the feature(s) recited in each claim element are fully disclosed in the patent application as filed, i.e., the '452 App. This disclosure includes a written description (and drawings), that would enable a POSITA to make and use a UAV as claimed. *See* 35 U.S.C. § 112. In the discussion below, for each claim element I point out the portions of the specification that support the corresponding feature(s) of that claim element. Because all of the claim elements of the proposed substitute claims are fully disclosed in the application as filed, in my opinion, the proposed substitute claims do not introduce new subject matter and also meet the written description and enablement requirements.

1. Proposed substitute claim 21 (Substitute for Claim 1)

a [21.pre] “A method of performing a flight control operation of a reference aerial vehicle, comprising:”

107. Support for the preamble is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[1]]21.[pre] A method of performing a flight control operation of a reference aerial vehicle, comprising:	EX2019, Title (“Flight Control Using Computer Vision”), Abstract (“A flight control operation of a reference aerial vehicle is performed”), ¶ 34 (“A flight control operation is performed based on three-dimensional relative location”), ¶ 59 (“The CPU may be configured to perform one or more flight decisions for the UAV. For example, the CPU may provide one or more flight commands to a flight controller module. For example, a flight command may include a specified speed for the UAV, a specified flight height for the UAV, a particular flight path for the UAV, etc. In response to the one or more flight commands, the flight controller module is configured to control the motors associated with the UAV (e.g., motors 304a, 304b) so that UAV 301 flies in a manner that is consistent with the flight commands” and “and in some “embodiments, the CPU is configured to autonomously fly UAV 301”), ¶ 90 (“a reference system (e.g., interceptor aerial vehicle 102 of Figure 1”), Figures 1-3B; EX1001, Title, Abstract, 3:41-42, 9:38-51, 16:13-18, FIGS. 1-3B.. <i>See</i> EX2019, ¶ 74 (“An interdiction control module may provide or suggest course corrections directly to the flight controller module to maneuver UAV 301 into an ideal interception position autonomously”), ¶ 78 (“In the example shown, side view 360 includes unmanned aerial vehicle 301 comprising computing chassis 302, UI panel 350, flight controller module 352”), ¶ 59 (Computing chassis 302 is configured to protect the CPU of UAV 301), ¶ 80 (“Flight controller module 352 is configured to control a flight of UAV 301”), Figure 2 (processor 211), Figure 3B; <i>see also</i> EX1001, 9:25-26, 12:64-67, 13:49-61, 14:5-6, FIGS. 2, 3B.

108. The above-cited portions of the '452 App. teach that a computing chassis 302 on-board a UAV contains a CPU, and the CPU provides flight control commands to a flight controller module to control flight of the UAV. Such commands may specify the speed, height, and/or flight path for the UAV. Thus, at least by providing the flight control commands, the CPU on-board the UAV executes a “method of performing a flight control operation of a reference aerial vehicle.” Thus, the '452 App. teaches the preamble of claim 1.

b [21.a] “receiving at a processor at the reference aerial vehicle an image captured by an image sensor of the reference aerial vehicle;”

109. Support for this claim element is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[21.a] <u>receiving at a processor at the reference aerial vehicle</u> an image captured by an image sensor of the reference aerial vehicle;	EX2019, ¶ 90 (“At 406, a relative location of the target is detected using a captured image . For example, once an image sensor/camera on a reference system (e.g., interceptor aerial vehicle 102 of Figure 1) is within range to acquire an image of the target, the reference system is able to more accurately detect and automatically navigate to the location of the target based at least in part on the image sensor/camera data . In some embodiments, once the reference system is within a predetermined distance (e.g., 20 meters) from the received location and the image sensor/camera is pointing towards the direction of the received location, captured images are analyzed using a processor of the reference system in an attempt to detect the target aerial

Claim Element	Support in the Specification
	vehicle in the image using computer machine vision”), FIG. 4; EX1001, 16:11-25, FIG. 4. EX2019, ¶ 94 (“an image sensor/camera of the interceptor aerial vehicle continually captures a stream of images in one or more directions including in the direction of travel of the interceptor aerial vehicle and each captured image is analyzed to identify a target aerial vehicle in the image, if possible. The detection of the target in the captured image may be performed using machine/computer vision”), FIG. 5; EX1001, 17:20-27, FIG. 5. <i>See</i> EX2019 ¶ 55 (“Unmanned Aerial Vehicle 200 may include a camera system 212. Camera system 212 may be used to visually detect a UAV. Camera system 212 may visually detect an object and provide visual data (e.g., pixel data) to one of the one or more machine learning models 205”), Figure 2; EX1001, 8:48-52, FIG. 2.

110. The above-cited portions of the ’452 App. teach that a camera on-board a UAV includes an “image sensor of the reference aerial vehicle.” The processor on board the UAV receives and analyzes the images captured by the camera using machine/computer vision, i.e., by applying a machine learning model to the captured images. Accordingly, the ’452 App. teaches claim element [21.a].

- c [21.b] “detecting at the reference aerial vehicle a target in the image including by applying at the reference aerial vehicle a machine learning model to the image, to identify a bounding box outlining a portion of the image that includes detected features of the target, and to identify a classification of the detected target;”*

111. Support for this claim element is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[21.b] <u>detecting at the reference aerial vehicle a target in the image including by applying at the reference aerial vehicle a machine learning model to the image, to identify a bounding box outlining a portion of the image that includes detected features of the target, and to identify a classification of the detected target;</u>	<i>See supra</i> element [21.a]; EX2019, ¶ 34 (“an image is received and a target aerial vehicle is detected in the image. For example, a stream of images captured by one or more cameras of an interceptor aerial vehicle is analyzed using deep learning, neural networks, and/or other machine learning techniques to recognize a target aerial vehicle in the captured image”); EX1001, 3:31-36. EX2019, ¶ 86 (“Figure 4 is a flowchart illustrating ... a process for automatically controlling flight of a vehicle. In some embodiments, the process of Figure 4 is performed by interceptor aerial vehicle 102 of FIG. 1. UAV 200 of FIG. 2, and/or UAV 301 of FIGS. 3A and 3B”), Figure 4; EX1001, 15:27-31, FIG. 4. EX2019, ¶ 90 (“[a]t 406, a relative location of the target is detected using a captured image. For example, once an image sensor/ camera on a reference system (e.g., interceptor aerial vehicle 102 of FIG. 1) is within range to acquire an image of the target, the reference system is able to more accurately detect and automatically navigate to the location of the target based at least in part on the image sensor/camera data. In some embodiments, once the reference system is within a predetermined distance (e.g., 20 meters) from the received location and the image sensor/camera is pointing towards the

Claim Element	Support in the Specification
	direction of the received location, captured images are analyzed using a processor of the reference system in an attempt to detect the target aerial vehicle in the image using computer machine vision”), Figure 4; EX1001, 16:11-25, FIG. 4. EX2019, ¶ 94 (“[t]he detection of the target in the captured image may be performed using machine/computer vision. For example, using a machine learning model trained using training data of various different images of targets, the captured image is analyzed to identify the target aerial vehicle in the image. The output of the image analysis (e.g., output from applying the machine learning model) may include a bounding box outlining an area within the image that includes the image portion with the target (e.g., bounding box outlines the minimum sized box that includes detected features of the target) and/or a classification of the detected target (e.g., type, model, class, manufacturer, size, etc. of the detected target)”); EX1001, 17:25-38. <i>See also</i> EX2019, ¶ 50 (“The one or more machine learning models 205 may be configured to implement one or more machine learning algorithms (e.g., support vector machine, soft max classifier, autoencoders, naive bayes, logistic regression, decision trees, random forest, neural network, deep learning, nearest neighbor, etc.)”); EX1001, 7:27-32.

112. The above-cited portions of the ’452 App., teach that the process of FIG. 4 is performed at the reference aerial vehicle. Per that process, captured images are analyzed by applying a machine learning model to detect a target in the image. Moreover, in view of the discussion above for claim element [21.a], the

portions of the '452 App. that are cited in connection with this claim element teach that a processor of the UAV analyzes captured images via computer/machine vision, i.e., by applying a machine learning model on-board a UAV to the captured image. The machine learning model can detect a target in the image. As part of detecting the target, the machine learning model, that may implement a neural network, identifies a bounding box outlining a portion of the captured image where that portion includes the target and its detected features and/or target classification. Thus, the '452 App. teaches claim element [21.b].

d [21.c] “determining at the reference aerial vehicle a three-dimensional relative location of the target with respect to the reference aerial vehicle based on the image including by determining a distance to the target based at least in part on a size of the bounding box of the target detected within the image and on a physical size corresponding to the classification of the target detected within the image; and

113. Support for this claim element is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[21.c] <u>determining at the reference aerial vehicle a three-dimensional relative location of the target with respect to the reference aerial vehicle based on the image including by determining a distance to the target based at least in part on a size of the bounding box of the target</u>	EX2019, ¶ 34 (“A three-dimensional relative location of the target aerial vehicle is determined with respect to a reference aerial vehicle based on the image . For example, azimuth and attitude directions as well as distance from the reference aerial vehicle are determined based on the image”); EX1001, 3:36-41. EX2019, ¶ 90 (“[a] distance value to the target and/or desired speed/acceleration may also be specified for the relative location ”); <i>id.</i> (“In some

Claim Element	Support in the Specification
detected within the image and on a <u>physical size corresponding to the classification of the target detected within the image</u>; and	embodiments, the relative location is specified by an azimuth angle and an altitude angle. A distance value to the target and/or desired speed/acceleration may also be specified for the relative location. In some embodiments, the relative location is specified by a three-dimensional vector determined based on the detected image of the target”); EX1001, 16:42-47. EX2019, ¶ 93 (“Figure 5 is a flowchart illustrating ... a process for determining a vector associated with a target. In some embodiments, the process of Figure 5 is performed by interceptor aerial vehicle 102 of FIG. 1, UAV 200 of FIG. 2, and/or UAV 301 of FIGS. 3A and 3B. In some embodiments, at least a portion of the process of FIG. 5 is performed in 406 and/or 408 of Figure 4”), Figures 4, 5; EX1001, 17:8-14, FIGS. 4, 5. EX2019, ¶ 96 (“[a]t 504, a relative direction to the target is determined based on the image”); <i>id.</i> (“For example, the output of the image analysis (e.g., output from applying the machine learning model) may include a bounding box identifying an area within the image that includes the target and the center of the bounding box can be used as a representative central point for the target. In other examples, another type of point on the target within the image may be selected as the representative point for the target (e.g., specifically identified point on a body of the target). The location (e.g., x and y location) of this representative point within the image is determined (e.g., pixel location). This two-dimensional location represents the relative direction of the target with respect to the reference as this two-dimensional location can be mapped to a corresponding azimuth angle and altitude angle”), Figure 5; EX1001, 18:12-37, FIG. 5. EX2019, ¶ 97 (“[a]t 506, a vector identifying the relative location of the target is determined using

Claim Element	Support in the Specification
	at least the determined relative direction of the target. For example, determined angular directions (e.g., azimuth angle and altitude angle) can be mapped to a three-dimensional vector identified by three axial components (e.g., x-axis, y-axis, and z-axis values)”), FIG. 5; EX1001, 18:44-49, FIG. 5. EX2019, ¶ 94 (“[t]he output of the image analysis (e.g., output from applying the machine learning model) may include a bounding box outlining an area within the image that includes the image portion with the target (e.g., bounding box outlines the minimum sized box that includes detected features of the target) and/or a classification of the detected target (e.g., type, model, class, manufacturer, size, etc. of the detected target)”); EX1001, 17:31-38. EX2019, ¶ 94 (“At 502, a relative distance to a target is determined based on a captured image of the target”), ¶ 95 (“In some embodiments, the relative distance to the target identifies the relative distance between a reference system (e.g., interceptor aerial vehicle) and the target (e.g., target aerial vehicle). The relative distance may be determined based on a size of the bounding box within the entire captured image and a detected classification of the target. For example, the target that is further away will appear smaller in the image as compared to the target that is closer to the reference location, and thus the size of the detected target within the image can be used as a proxy for the distance to the target. However, different types of target aerial vehicles may be different sizes and the actual physical size of the target needs to be taken into account when using the target size within the image as a proxy for relative distance. In some embodiments, the machine learning model has been trained using different examples of types of aerial vehicles (e.g., different models, types,

Claim Element	Support in the Specification
	manufacturers, sizes, etc.) to be able to classify and identify the specific type of the detected target aerial vehicle and a corresponding size profile corresponding to the specific type”), FIG. 5; EX1001, 17:17-18, 17:39-58, FIG. 5. EX2019, ¶ 95 (“Thus, a measurement of the target within the image (e.g., width of the bounding box, length of the bounding box, diagonal length of the bounding box, area of the bounding box, number of pixels in the bounding box, number of pixels across a dimension of the bounding box, etc.) can be mapped to a distance value based on a determined size corresponding to the detected type/classification of the target”); EX1001, 17:61-67. <i>See also</i> EX2019, ¶ 51 (“In some embodiments, the output of a machine learning model trained to identify UAVs may be provided to one or more other machine learning models that are trained to identify specific UAV models. The velocity profile of a UAV may follow a general micro-Doppler signature, but within the general micro-Doppler signature, different types of UAVs may be associated with different micro-Doppler signatures”); EX1001, 7:42-49.

114. The above-cited portions of the ’452 App. teach that the process of Figure 5 is performed at the reference aerial vehicle. That process includes applying a machine learning model to identify a bounding box for the detected target and to determine a specific type and/or classification of the target. The process also determines a relative direction to the target in a three-dimensional space and a relative distance to the target, i.e., a distance from the UAV. The

distance is determined using the bounding box for the target and the physical size corresponding to the identified classification and/or type of the target. The on-board application of the machine learning model thus identifies the relative direction and the relative distance, i.e., the three-dimensional location of the target relative to that of the UAV. As such, the '452 App. teaches claim element [21.c].

e [21.d] “performing at the reference aerial vehicle the flight control operation based on the three-dimensional relative location of the target with respect to the reference aerial vehicle, wherein performing the flight control operation includes determining a speed adjustment factor based on a magnitude of deviation of a direction of the three-dimensional relative location with respect to a current flight direction of the reference aerial vehicle.”

115. Support for this claim element is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[21.d] performing at the reference aerial vehicle the flight control operation based on the three-dimensional relative location of the target with respect to the reference aerial vehicle, wherein performing the flight control operation includes determining a speed adjustment factor based on a magnitude of deviation of a direction of the three-dimensional relative location with respect to a	EX2019, ¶ 34 (“A flight control operation is performed based on three-dimensional relative location”), ¶ 59 (“The CPU may be configured to perform one or more flight decisions for the UAV. For example, the CPU may provide one or more flight commands to a flight controller module. For example, a flight command may include a specified speed for the UAV, a specified flight height for the UAV, a particular flight path for the UAV, etc. In response to the one or more flight commands, the flight controller module is configured to control the motors associated with the UAV (e.g., motors 304a, 304b) so that UAV 301 flies in a manner that is consistent with the flight commands” and in some “embodiments, the CPU is

Claim Element	Support in the Specification
current flight direction of the reference aerial vehicle.	configured to autonomously fly UAV 301”)), FIGS. 3A-B; EX1001, 3:41-42, 9:38-51, FIGS. 3A-B. EX2019, ¶ 97 (“At 506, a vector identifying the relative location of the target is determined using at least the determined relative direction of the target”); <i>id.</i> (“In some embodiments, the vector is at least in part defined using a distance and/or speed value. For example, the distance value determined in 502 is mapped to a desired speed of travel to reach the target (e.g., greater speed desired for further distance and slower speed desired for shorter distance to allow more time for direction correction) and the length of the vector is based on the determined distance and/or speed”), ¶ 98 (“At 508, the vector is scaled. In some embodiments, scaling the vector includes modifying a speed and/or acceleration associated with the vector as well as smoothing and limiting the rate of change associated with the vector”), FIG. 5; EX1001, 18:44-59, 18:65-19:1, FIG. 5. EX2019, ¶ 99 (“Modifying the speed and/or acceleration associated with the vector includes adjusting a factor used to control the speed and/or acceleration of the interceptor aerial vehicle based on an amount of directional change specified by the vector. For example, when a large directional change is required by the interceptor aerial vehicle to fly towards the target, a slower speed is desirable to allow the directional change to take place at a slower speed over a shorter distance as compared to a faster speed that is desirable to reach the target quicker when no or minor directional change is required. In some embodiments, the speed and/or acceleration factor is multiplied by one or more scalar values that change in magnitude based on a directional deviation of the vector from a current direction of movement (e.g., deviation of the target in the

Claim Element	Support in the Specification
	image from the center of the image representing the current heading direction of the interceptor aerial vehicle); EX1001, 19:4-20.

116. The above-cited portions of the '452 App. teach that the UAV performs its flight-control operations autonomously, including parts of the process of Figure 5, at the UAV, using a processor on-board the UAV. As part of performing the flight control operations, the on-board processor may perform a speed adjustment, where the speed adjustment depends in part of the magnitude of the angle of the direction pointing to the target's three dimensional location relative to the UAV's heading, i.e., the UAV's current flight direction. Accordingly, the '452 App. teaches claim element [21.d].

117. In summary, the '452 App. discloses, and thus, the '711 patent teaches each and every element of proposed substitute claim 21.

2. Proposed Substitute Claim 22 (Substitute for Claim 2)

118. Proposed substitute claim 22 recites: “[t]he method of claim 21, wherein the reference aerial vehicle is a multicopter unmanned aerial vehicle and the target is an aerial vehicle.”

119. Support for proposed substitute claim 22 is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[2]]22. The method of claim 21, wherein the reference aerial vehicle is a multirotor unmanned aerial vehicle and the target is an aerial vehicle.	EX2019, ¶ 35 (“Examples of interceptor aerial vehicle 102 include a drone, a multirotor aircraft”), ¶ 36 (an “example of the unauthorized aerial vehicle is target aerial vehicle 110 (e.g., a drone”), ¶ 57 (“ Unmanned aerial vehicle 301 is an example of UAV 200 of Figure 2 and/or aerial vehicle 102 of Figure 1”), at 73 (claim 2), Figures 1, 2; EX1001, 3:46-50, 9:7-10, FIGS. 1, 2.

120. Thus, the ’452 App. disclose as an interceptor vehicle, i.e., a reference aerial vehicle, a UAV that is a multirotor UAV. The ’452 App. also discloses a target that is an aerial vehicle or a drone. Accordingly, the ’452 App. teaches the limitations recited in proposed substitute claim 22.

3. Proposed Substitute Claim 23 (Substitute for Claim 3)

121. Proposed substitute claim 23 recites: “[t]he method of claim 21, wherein performing the flight control operation includes one or more of the following: turning the reference aerial vehicle towards the target, adjusting a speed of the reference aerial vehicle, or engaging a mechanism to capture the target.”

122. Support for proposed substitute claim 23 is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[3]]23. The method of claim 21, wherein performing the flight control operation includes one or more of the following: turning the	EX2019, ¶ 91 (“[a]t 408, a flight operation is performed based on the detected relative location of the target. For example, a flight direction and/or speed of an interceptor aerial vehicle are automatically and autonomously adjusted based on a location and size of the target within the captured

Claim Element	Support in the Specification
reference aerial vehicle towards the target, adjusting a speed of the reference aerial vehicle, or engaging a mechanism to capture the target.	image (e.g., adjust direction to center the target within subsequently captured images). This allows the flight path of the interceptor aerial vehicle to be dynamically adjusted to track and follow a moving target, allowing the interceptor aerial vehicle to come within a threshold distance where an interdiction/capture system (e.g., a net fired from the interceptor aerial vehicle) can be effectively deployed. In some embodiments, a scaled three-dimensional vector based on the relative location of the target and determined based on the detected image of the target is used to adjust a flight path of the interceptor aerial vehicle in the direction and intensity of the three-dimensional vector. For example, the three-dimensional vector specifies directional and speed/acceleration changes to be performed by the interceptor aerial vehicle to direct the flight path of the interceptor aerial vehicle at a desired rate of change towards the target aerial vehicle”), Figure 4; EX1001, 16:49-17:3, FIG. 4. <i>See</i> EX2019 ¶ 33 (“when a threatening UAV is detected, the interceptor aerial vehicle may be deployed to fly to the target UAV and capture it (e.g., using a net fired from the interceptor aerial vehicle over the target to capture the target in the net for transport to a safe location)), ¶ 52 (“[i]nterdiction system 207 includes a capture net launcher 208”), ¶ 97 (“the distance value determined in 502 is mapped to a desired speed of travel to reach the target”), at 73 (claim 3), Figure 2; EX1001, 3:16-21, 7:55-56; 18:54-59, FIG. 2.

123. Thus, the ’452 App. teaches changing the direction and speed of an interceptor aerial vehicle, i.e., a reference aerial vehicle, “to direct the flight path of the interceptor aerial vehicle ... towards the target aerial vehicle,” and thus “to

reach the target.” As such, the ’452 App. teaches “turning the reference aerial vehicle towards the target,” and “adjusting a speed of the reference aerial vehicle.” The ’452 App. also teaches “using a net fired from the interceptor aerial vehicle over the target to capture the target in the net,” i.e., “engaging a mechanism to capture the target.” As such, the ’452 App. teaches the limitations recited in proposed substitute claim 23.

4. Proposed Substitute Claim 24 (Substitute for Claim 4)

124. Proposed substitute claim 24 recites: “[t]he method of claim 21, wherein detecting the target in the image including by applying at the reference aerial vehicle the machine leaning model to the image includes identifying a model type of the target based on the classification of the detected target.”

125. Support for proposed substitute claim 24 is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[4]]24. The method of claim 21, wherein detecting the target in the image <u>including by applying at the reference aerial vehicle the machine leaning model to the image</u> includes identifying a model type of the target <u>based on the classification of the detected target.</u>	EX2019, ¶ 94 (“The detection of the target in the captured image may be performed using machine/computer vision. For example, using a machine learning model trained using training data of various different images of targets, the captured image is analyzed to identify the target aerial vehicle in the image. The output of the image analysis (e.g., output from applying the machine learning model) may include a bounding box outlining an area within the image that includes the image portion with the target (e.g., bounding box outlines the minimum sized box that includes detected features of the target) and/or a

Claim Element	Support in the Specification
	classification of the detected target (e.g., type , model, class, manufacturer, size, etc. of the detected target ”); EX1001, 17:25-38. EX2019, ¶ 95 (“In some embodiments, the machine learning model has been trained using different examples of types of aerial vehicles (e.g., different models , types, manufacturers, sizes, etc.) to be able to classify and identify the specific type of the detected target aerial vehicle”); EX1001, 17:53-58.

126. The ’452 App. teaches that the “the machine learning model” may perform a classification according to different models to “identify the specific type,” e.g., the specific model type “of the detected target aerial vehicle.” Accordingly, the ’452 App. teaches proposed substitute claim 24.

5. Proposed Substitute Claim 25 (Substitute for Claim 8)

127. Proposed substitute claim 25 recites: “[t]he method of claim 21 wherein performing the flight control operation includes determining a speed adjustment factor based on the determined distance to the target.”

128. Support for proposed substitute claim 25 is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[8]]25. The method of claim [[7]]21 wherein performing the flight control operation includes determining a speed adjustment factor based on	EX2019, ¶ 90 (“[a]t 406, a relative location of the target is detected using a captured image”); <i>id.</i> ¶ 91 (“[a]t 408, a flight operation is performed based on the detected relative location of the target”); <i>id.</i> ¶ 90 (“[i]n some embodiments, the relative location is specified by a three-dimensional vector ”), ¶ 91 (“[i]n some embodiments, a scaled three-

Claim Element	Support in the Specification
the determined distance to the target.	dimensional vector based on the relative location of the target ... is used to adjust a flight path of the interceptor aerial vehicle in the direction and intensity of the three-dimensional vector. For example, the three-dimensional vector specifies directional and speed/acceleration changes to be performed by the interceptor aerial vehicle to direct the flight path of the interceptor aerial vehicle at a desired rate of change towards the target aerial vehicle”), Figure 4; EX1001, 16:11-12, 44-47, 16:49-50, 16:60-17:3, FIG. 4. EX2019, ¶ 97 (“[a]t 506, a vector identifying the relative location of the target is determined using at least the determined relative direction of the target”); <i>id.</i> (“[i]n one example, the vector is defined by the azimuth angle, the altitude angle, and a factor based on an associated distance or speed”); <i>id.</i> (“[i]n some embodiments, the vector is at least in part defined using a distance and/or speed value. For example, the distance value determined in 502 is mapped to a desired speed of travel to reach the target (e.g., greater speed desired for further distance and slower speed desired for shorter distance to allow more time for direction correction)”), at 73 (claim 8), Figure 5; EX1001, 18:44-64, FIG. 5.

129. Thus, the '452 App. describes a vector for performing flight control operations, where the vector includes a factor based on speed that is based on the distance to the target. Accordingly, the '452 App. teaches the limitations recited in proposed substitute claim 25.

6. Proposed Substitute Claim 26 (Substitute for Claim 9)

130. Proposed substitute claim 26 recites: “[t]he method of claim 21, wherein determining the three-dimensional relative location of the target includes determining a direction of the target with respect to the reference aerial vehicle.”

131. Support for proposed substitute claim 26 is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[9]]26. The method of claim 21, wherein determining the three-dimensional relative location of the target includes determining a direction of the target with respect to the reference aerial vehicle.	EX2019, ¶ 34 (“[a] three-dimensional relative location of the target aerial vehicle is determined with respect to a reference aerial vehicle based on the image. For example, azimuth and attitude directions as well as distance from the reference aerial vehicle are determined based on the image”), ¶ 90 (“[a]t 406, a relative location of the target is detected using a captured image”); <i>id.</i> ¶ 91 (“[a]t 408, a flight operation is performed based on the detected relative location of the target”); <i>id.</i> ¶ 90 (“[i]n some embodiments, the relative location is specified by a three-dimensional vector ”), ¶ 97 (“[a]t 506, a vector identifying the relative location of the target is determined using at least the determined relative direction of the target . For example, determined angular directions (e.g., azimuth angle and altitude angle) can be mapped to a three-dimensional vector identified by three axial components (e.g., x-axis, y-axis, and z-axis values)”), at 74 (claim 9), Figures 4, 5; EX1001, 3:36-41, 16:11-12, 16:44-47, 16:49-50, 18:44-49, FIGS. 4, 5.

132. Thus, the ’452 App. discloses that the three-dimensional relative location of the target is based on, in part, the relative direction of the target with

respect to the reference aerial vehicle, e.g., in terms of the azimuth and altitude angles. Thus, the '452 App. teaches the limitations recited in proposed substitute claim 26.

7. Proposed Substitute Claim 27 (Substitute for Claim 10)

133. Proposed substitute claim 27 recites: “[t]he method of claim 21, wherein determining the three-dimensional relative location of the target includes determining an azimuth angle and an altitude angle to the target from the reference aerial vehicle.”

134. Support for proposed substitute claim 27 is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[10]]27. The method of claim 21, wherein determining the three-dimensional relative location of the target includes determining an azimuth angle and an altitude angle to the target from the reference aerial vehicle.	<i>See supra</i> proposed substitute claim 26 (describing determining the three-dimensional relative location of the target is based on, in part, the azimuth and altitude angles); EX2019 at 74 (claim 10).

135. As such, the '452 App. teaches the limitations recited in proposed substitute claim 27.

8. Proposed Substitute Claim 28 (Substitute for Claim 11)

136. Proposed substitute claim 28 recites: “[t]he method of claim 21, wherein determining the three-dimensional relative location of the target includes converting a two-dimensional vector to a three-dimensional vector representing the three-dimensional relative location.”

137. Support for proposed substitute claim 28 is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[11]]28. The method of claim 21, wherein determining the three-dimensional relative location of the target includes converting a two-dimensional vector to a three-dimensional vector representing the three-dimensional relative location.	EX2019, ¶ 103 (“Figure 7 is an illustration illustrating an example of a three dimensional vector determined using two dimensional measurements . 3D vector 700 comprises a target 702, a UD factor 704, an LR factor 706, and an FB factor 708. Target 702, which is associated with a 2D vector, has a 3D vector determined, which may comprise the UD factor 704, the LR factor 706, and the FB factor 708. The UD factor 704, the LR factor 706, and the FB factor 708 may be calculated using the example equations shown in Figure 8”), ¶ 104 (“Figure 8 shows example equations that can be utilized to determine a three dimensional vector . The equations are based on measurements for two axes of an image, such as an x-axis (degX) and a y-axis (degY). An initial 2D vector may be determined based on the location of the target pixels. The 2D vector is then converted into a 3D vector comprising three factors: an up/down factor (UD), a front/back factor (FB), and a left/right factor (LR). The conversion may be performed utilizing the equations shown in Figure 8”), at 74 (claim 11), Figures 7, 8; EX1001, 20:29-46, FIGS. 7, 8.

138. Thus, the '452 App. teaches the limitations recited in proposed substitute claim 28.

9. Proposed Substitute Claim 29 (Substitute for Claim 12)

139. Proposed substitute claim 29 recites: “[t]he method of claim 21, further comprising: receiving a geographical location associated with the target detected at least in part using a ground-based sensor; autonomously navigating the reference aerial vehicle towards the received geographical location; and determining to allow image-based navigation.”

140. Support for proposed substitute claim 29 is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[12]] <u>29</u> . ^[pre] The method of claim <u>21</u> , further comprising:	<i>See supra</i> proposed substitute claim 21.
[29.a] receiving a geographical location associated with the target detected at least in part using a ground-based sensor;	EX2019, ¶ 87 (“[a]t 402, a location of a target is received . An example of the location is geographical location coordinate and an example of the target is a vehicle detected to be not allowed in a monitored airspace (e.g., target aerial vehicle 110 of Figure 1). In some embodiments, the location is a geographical location coordinate that has been determined using one or more remote sensors . For example, the location of target aerial vehicle 110 is provided by ground station 104 via a wireless communication to interceptor aerial vehicle 102, and ground station 104 has determined the location based on information from sensors of ground station 104 and/or ground-based sensor 106 of Figure 1. In some embodiments, the location is received directly from one or more different sensors

Claim Element	Support in the Specification
	(e.g., from one or more ground-based sensors)”), at 74-75 (claim 17), Figure 4; EX1001, 15:32-45, FIG. 4.
[29.b] autonomously navigating the reference aerial vehicle towards the received geographical location; and	EX2019, ¶ 89 (“[a]t 404, the received location is utilized to navigate towards the received location. For example, the location is received at a navigation component and/or a flight controller of an interceptor aerial vehicle and the direction and/or speed of the aerial vehicle is automatically and autonomously adjusted to turn and fly towards the received location in a navigation mode based on the received location”), at 74-75 (claim 17), Figure 4; EX1001, 15:64-16:3, FIG. 4.
[29.c] determining to allow image-based navigation.	EX2019, ¶ 89 (navigation based on the received location “allows the interceptor aerial vehicle to be approached and become closer to the vicinity of the target. However, because the received location may represent a rough and/or approximate location of the target, the received location may not represent the exact location of a moving target required to be known to successfully deploy an interdiction/capture mechanism.”), ¶ 90 (“[a]t 406, a relative location of the target is detected using a captured image. For example, once an image sensor/camera on a reference system (e.g., interceptor aerial vehicle 102 of Figure 1) is within range to acquire an image of the target, the reference system is able to more accurately detect and automatically navigate to the location of the target based at least in part on the image sensor/camera data. In some embodiments, once the reference system is within a predetermined distance (e.g., 20 meters) from the received location and the image sensor/camera is pointing towards the direction of the received location, captured images are analyzed using a processor of the reference system in an attempt to detect the target aerial vehicle in the image using computer machine

Claim Element	Support in the Specification
	vision. If the target aerial vehicle is not detected in the captured image, the reference system continues to proceed towards the received location in the received location-based navigation mode. However, once the target is detected in a captured image, the navigation of the reference system may now be performed based on the image rather than or in addition to the received location”), at 74-75 (claim 17), Figure 4; EX1001, EX1001, 16:3-31, FIG. 4. <i>See also, infra</i> (proposed substitute claim 35) (describing switching from received location based navigation to captured imaged based navigation, when the reference aerial vehicle is within a predetermined / threshold distance from the received location).

141. Thus, the ’452 App. teaches allowing image-based navigation when a target is detected in the image and/or when the reference aerial vehicle is within a predetermined / threshold distance from the received location. Accordingly, the ’452 App. teaches the limitations recited in proposed substitute claim 29.

10. Proposed Substitute Claim 30 (Substitute for Claim 13)

142. Proposed substitute claim 30 recites: “[t]he method of claim 21, wherein the speed adjustment factor is greater for a smaller magnitude of deviation as compared to for a greater magnitude of deviation.”

143. Support for proposed substitute claim 30 is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[13]]30. The method of claim 21, wherein the speed adjustment factor is greater for a smaller magnitude of deviation as compared to for a greater magnitude of deviation.	EX2019, ¶ 99 (“[i]n some embodiments, the speed and/or acceleration factor is multiplied by one or more scalar values that change in magnitude based on a directional deviation of the vector from a current direction of movement (e.g., deviation of the target in the image from the center of the image representing the current heading direction of the interceptor aerial vehicle”); <i>id.</i> (“[m]odifying the speed and/or acceleration associated with the vector includes adjusting a factor used to control the speed and/or acceleration of the interceptor aerial vehicle based on an amount of directional change specified by the vector. For example, when a large directional change is required by the interceptor aerial vehicle to fly towards the target, a slower speed is desirable to allow the directional change to take place at a slower speed over a shorter distance as compared to a faster speed that is desirable to reach the target quicker when no or minor directional change is required”), at 74 (claim 13); EX1001, 19:4-14.

144. Thus, the ’452 App. teaches that the speed adjustment factor can be adjusted in an opposite manner to the required directional change, i.e., a greater speed adjustment for a smaller directional change and vice versa. Therefore, the ’452 App. teaches the limitations recited in proposed substitute claim 30.

11. Proposed Substitute Claim 31 (Substitute for Claim 14)

145. Proposed substitute claim 31 recites “[t]he method of claim 21, wherein performing the flight control operation includes scaling a speed

adjustment factor to smooth and limit a rate of change of a speed of the reference aerial vehicle.”

146. Support for proposed substitute claim 31 is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[14]]31. The method of claim 21, wherein performing the flight control operation includes scaling a speed adjustment factor to smooth and limit a rate of change of a speed of the reference aerial vehicle.	<i>See supra</i> proposed substitute claim 25 (describing that the flight control operation may be performed using a vector relating to the target location); EX2019, ¶ 91 (“the three-dimensional vector specifies directional and speed/acceleration changes to be performed by the interceptor aerial vehicle to direct the flight path of the interceptor aerial vehicle at a desired rate of change towards the target aerial vehicle”), ¶ 98 (“[a]t 508, the vector is scaled. In some embodiments, scaling the vector includes modifying a speed and/or acceleration associated with the vector as well as smoothing and limiting the rate of change associated with the vector”), ¶ 99 (“[i]n some embodiments, the factor used to control the speed and/or acceleration of the interceptor aerial vehicle includes limiting its rate of change and/or value (e.g., either by a reduction scalar or a maximum change limit) so that the interceptor aerial vehicle does not change its speed in a manner that is too sudden or difficult to achieve given flight hardware limitations”), at 74 (claim 14), Figure 5; EX1001, 16:65-17:3, 18:65-19:1, 19:36-42, FIG. 5.

147. A factor used to control the speed and to scale the vector to modify the speed to avoid sudden changes in the speed is an adjustment factor that smooths

and limits the rate of change of the reference aerial vehicles speed. Thus, the '452 App. teaches the limitations recited in proposed substitute claim 31.

12. Proposed Substitute Claim 32 (Substitute for Claim 15)

148. Proposed substitute claim 32 recites: “[t]he method of claim 21, wherein performing the flight control operation includes determining a direction adjustment factor based on a magnitude of deviation of a direction of the three-dimensional relative location with respect to a current flight direction of the reference aerial vehicle.”

149. Support for proposed substitute claim 32 is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[15]]32. The method of claim 21, wherein performing the flight control operation includes determining a direction adjustment factor based on a magnitude of deviation of a direction of the three-dimensional relative location with respect to a current flight direction of the reference aerial vehicle.	<i>See supra</i> proposed substitute claim 25 (describing that the flight control operation may be performed using a vector relating to the target location); EX2019, ¶ 100 (“[i]n some embodiments, the scaling the vector includes modifying one or more directional component values of the vector”); <i>id.</i> (“[i]n some embodiments, the one or more component values of the vector are multiplied by one or more scalar values that change in magnitude based on a deviation of the corresponding component value from a center reference value (e.g., corresponding to a current direction of movement)”), at 74 (claim 15), Figure 5; EX1001, 19:1-3, 19:14-20, FIG. 5.

150. Determining a scalar value that is multiplied with a direction component value is a “direction adjustment factor.” The scalar value is determined

based on a deviation of the direction component value, i.e., deviation of direction, corresponding to a current direction of movement, i.e., “direction of the three-dimensional relative location” of the target “with respect to a current flight direction of the reference aerial vehicle.” Accordingly, the ’452 App. teaches the limitations recited in proposed substitute claim 32.

13. Proposed Substitute Claim 33 (Substitute for Claim 16)

151. Proposed substitute claim 33 recites: “[t]he method of claim 21, wherein performing the flight control operation includes scaling the direction adjustment factor to smooth and limit a rate of change of a direction of the reference aerial vehicle.”

152. Support for proposed substitute claim 33 is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[16]]33. The method of claim [[15]]21, wherein performing the flight control operation includes scaling the direction adjustment factor to smooth and limit a rate of change of a direction of the reference aerial vehicle.	<i>See supra</i> proposed substitute claim 25 (describing that the flight control operation may be performed using a vector relating to the target location); EX2019, ¶ 98 (“[a]t 508, the vector is scaled . In some embodiments, scaling the vector includes modifying a speed and/or acceleration associated with the vector as well as smoothing and limiting the rate of change associated with the vector. In some embodiments, the scaling the vector includes modifying one or more directional component values of the vector”), ¶ 100 (“the scaling the vector includes modifying one or more directional component values of the vector. For example, a rate of change and/or a value of one or more components of the vector is limited (e.g., either by a

Claim Element	Support in the Specification
	reduction scalar value or a limit) so that the interceptor aerial vehicle does not change directions in a manner that is too sudden or difficult to achieve given flight hardware limitations. In one example, a magnitude of change of a component value of the vector is limited by a predetermined maximum limit. In some embodiments, the one or more component values of the vector are multiplied by one or more scalar values that change in magnitude based on a deviation of the corresponding component value from a center reference value (e.g., corresponding to a current direction of movement”), at 74 (claim 16), Figure 5; EX1001, 18:65-19:3, 19:45-59, FIG. 5.

153. A scalar value that is multiplied with a direction component value to avoid sudden direction changes is an adjustment factor that smooths and limits the rate of change of direction. Thus, the '452 App. teaches the limitations recited in proposed substitute claim 33.

14. Proposed Substitute Claim 34 (Substitute for Claim 17)

154. Proposed substitute claim 34 recites: “The method of claim 21, wherein the distance to the target is determined based at least in part using a radar.”

155. Support for proposed substitute claim 34 is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[17]]34. The method of claim 21, wherein the distance to the target is	EX2019, ¶ 87 (“[a]t 402, a location of a target is received. In some embodiments, the location is relative to a reference aerial vehicle” and “the

Claim Element	Support in the Specification
determined based at least in part using a radar.	location (e.g., including azimuth angle, altitude angle, distance) is determined using an on-vehicle sensor (e.g., radar sensor of UAV 301)”), Figures 3A-B, 4; EX1001, 3:46-50, 3:56-61, 3:64-67, 15:43-49, FIGS. 3A-B, 4.

156. As such, the ’452 App. teaches the limitations recited in proposed substitute claim 34.

15. Proposed Substitute Claim 35 (Substitute for Claim 18)

157. Proposed substitute claim 35 recites: “[t]he method of claim 21, wherein it is determined to allow the image-based navigation based on whether the reference aerial vehicle is within a threshold distance away from the received geographical location.”

158. Support for proposed substitute claim 35 is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[18]]35. The method of claim 21, wherein it is determined to allow the image-based navigation based on whether the reference aerial vehicle is within a threshold distance away from the received geographical location.	EX2019, ¶ 56 (“UAV 200 may use radar system 202 to detect an object that is greater than a threshold distance away. UAV 200 may use camera system 212 to detect an object that is less than or equal to the threshold distance away”), ¶ 90 (“[i]n some embodiments, once the reference system is within a predetermined distance (e.g., 20 meters) from the received location and the image sensor/camera is pointing towards the direction of the received location, captured images are analyzed using a processor of the reference system in an attempt to detect the target aerial vehicle in the image using computer machine vision. If the target aerial vehicle

Claim Element	Support in the Specification
	is not detected in the captured image, the reference system continues to proceed towards the received location in the received location-based navigation mode. However, once the target is detected in a captured image, the navigation of the reference system may now be performed based on the image rather than or in addition to the received location”), at 75 (claim 18), Figures 2, 4; EX1001, 8:66-9:2, 16:18-31, FIGS. 2, 4. <i>See</i> EX2019, ¶ 36 (“[w]hen an unauthorized aerial vehicle is detected (e.g., using sensors of ground station 104 and/or ground-based sensor 106), interceptor aerial vehicle 102 may be deployed to interdict/capture the unauthorized aerial vehicle”), <i>id.</i> (“[t]he detected location of target aerial vehicle 110 may be provided to interceptor aerial vehicle 102 to allow it to automatically and autonomously fly towards the direction of the detected location. However, once interceptor aerial vehicle 102 is near target aerial vehicle 110, the location data from ground-based sensors may not be accurate or updated fast enough for interceptor aerial vehicle 102 to get close enough to the moving target aerial vehicle 110 to reliably deploy a capture mechanism. Interceptor aerial vehicle 102 includes one or more computer vision sensors and a processor that can be used to dynamically detect the unauthorized aerial vehicle and autonomously navigate interceptor aerial vehicle 102 towards the target aerial vehicle”), Figure 1; EX1001, 4:7:26, FIG. 1. EX2019, ¶ 90 (“once an image sensor/camera on a reference system (e.g., interceptor aerial vehicle 102 of Figure 1) is within range to acquire an image of the target, the reference system is able to more accurately detect and automatically navigate to the location of the target based at least in part on the image sensor/camera data”), Figure 4; EX1001 16:12-18, FIG. 4.

159. Thus, the '452 App. describes using a camera on-board a UAV to detect a target when the UAV is within a predetermined / threshold distance from the received location of the target. Once the target is detected using the camera, the UAV is navigated using image-based navigation. Accordingly, the '452 App. teaches the limitations recited in proposed substitute claim 35.

16. Proposed Substitute Claim 36 (Substitute for Claim 19)

a [36.pre] “A reference aerial vehicle, comprising:”

160. Support for the preamble is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[19]]36.[pre] A reference aerial vehicle, comprising:	EX2019, Abstract (“A flight control operation of a reference aerial vehicle is performed”), ¶ 34 (“A three-dimensional relative location of the target aerial vehicle is determined with respect to a reference aerial vehicle ”), ¶ 90 (“a reference system (e.g., interceptor aerial vehicle 102 of Figure 1)”), FIGS. 1-3B; EX1001, Abstract, 3:36-39, 16:11-18.

161. The '452 App. discloses determining the relative location of a target UAV with respect to a reference aerial vehicle. The '452 App. also discloses an interceptor aerial vehicle as a “reference” system. Thus, the '452 App. teaches the preamble of claim 1.

b [36.a] “an image sensor configured to capture an image;”

162. Support for this claim element is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[36.a] an image sensor configured to capture an image;	EX2019, ¶ 90 (“At 406, a relative location of the target is detected using a captured image. For example, once an image sensor/camera on a reference system (e.g., interceptor aerial vehicle 102 of Figure 1) is within range to acquire an image of the target, the reference system is able to more accurately detect and automatically navigate to the location of the target based at least in part on the image sensor/camera data”), ¶ 94 (“For example, an image sensor/camera of the interceptor aerial vehicle continually captures a stream of images”), FIG. 4; EX1001, 16:11-18, 17:20-25. <i>See also</i> EX2019, ¶ 55 (“Unmanned Aerial Vehicle 200 may include a camera system 212. Camera system 212 may be used to visually detect a UAV”), ¶ 76 (“UAV 301 may include visual detection system 311. Visual detection system 311 may include one or more cameras”), FIGS. 2, 3A-B; EX1001, 8:48-50, 13:26-27, FIGS. 2, 3A-B.

163. The ’452 App. discloses an image sensor / camera that can capture a stream of images. Accordingly, the ’452 App. teaches claim element [36.a].

c [36.b1] “detect a target in the image; and”

164. Support for this claim element is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[36.b1] a processor configured to: detect a target in the image; and	<i>See supra</i> § XI.D.1.c (proposed substitute claim 21, element [21.b]).

165. Claim element [21.b] recites “detecting at the reference aerial vehicle a target in the image” It is disclosed in connection with claim element [21.b] that the detection is performed by a processor at the UAV. Accordingly, the ’452 App. teaches claim element [36.b1].

d [36.b2] “determine a three-dimensional relative location of the target with respect to the reference aerial vehicle based on the image; and”

166. Support for this claim element is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[36.b2] determine a three-dimensional relative location of the target with respect to the reference aerial vehicle based on the image; and	<i>See supra</i> § XI.D.1.d (proposed substitute claim 21, element [21.c]).

167. Substantially similar to claim element [36.b2], claim element [21.c] recites “determining at the reference aerial vehicle a three-dimensional relative location of the target with respect to the reference aerial vehicle based on the image....” Therefore, as discussed for claim element [21.c], the ’452 App. teaches claim element [36.b2].

- e [36.c] “a flight controller configured to perform a flight control operation based on the three-dimensional relative location of the target with respect to the reference aerial vehicle, wherein the flight controller is configured to perform the flight control operation including by being configured to determine a speed adjustment factor based on a magnitude of deviation of a direction of the three-dimensional relative location with respect to a current flight direction of the reference aerial vehicle,”*

168. Support for this claim element is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[36.c] a flight controller configured to perform a flight control operation based on the three-dimensional relative location of the target with respect to the reference aerial vehicle, wherein the flight controller is configured to perform the flight control operation including by being configured to determine a speed adjustment factor based on a magnitude of deviation of a direction of the three-dimensional relative location with respect to a current flight direction of the reference aerial vehicle[.].	See EX2019, ¶ 78 (“In the example shown, side view 360 includes unmanned aerial vehicle 301 comprising computing chassis 302, UI panel 350, flight controller module 352”), ¶ 59 (Computing chassis 302 is configured to protect the CPU of UAV 301), ¶ 80 (“Flight controller module 352 is configured to control a flight of UAV 301”), FIGS. 2 (processor 211), 3A-B; EX1001, 13:49-61, 9:25-26, 14:5-6, FIGS 2, 3A-B. EX2019, Title (“Flight Control Using Computer Vision”), Abstract (“A flight control operation of a reference aerial vehicle is performed”), ¶ 34 (“A flight control operation is performed based on three-dimensional relative location”), ¶ 59 (“The CPU may be configured to perform one or more flight decisions for the UAV. For example, the CPU may provide one or more flight commands to a flight controller module. For example, a flight command may include a specified speed for the UAV, a specified flight height for the UAV, a particular flight path for the UAV, etc. In response to the one or more flight commands, the flight controller module is configured to control the motors associated with the UAV (e.g., motors 304a, 304b) so that UAV 301 flies in a manner that is

Claim Element	Support in the Specification
	consistent with the flight commands” and that in some “embodiments, the CPU is configured to autonomously fly UAV 301”); EX1001, Title, Abstract, 3:41-42, 9:38-51. <i>See supra</i> § XI.D.1.e (proposed substitute claim 21, element [21.d] (reciting substantially the same limitations)).

169. The '452 App. discloses a flight controller that performs flight control operations according to flight commands specified by a CPU on-board the UAV. Moreover, like claim element [36.c], claim element [21.d] also recites “performing at the reference aerial vehicle the flight control operation based on the three-dimensional relative location of the target with respect to the reference aerial vehicle, wherein performing the flight control operation includes determining a speed adjustment factor based on a magnitude of deviation of a direction of the three-dimensional relative location with respect to a current flight direction of the reference aerial vehicle.” Accordingly, the '452 App. teaches claim element [36.c].

f [36.d] “wherein the detecting of the target in the image is performed using a neural network at a first robustness and a first compute cost, and the determining of the three-dimensional relative location of the target in the image comprises incrementally predicting the location of the target in the image at a second robustness and a second compute cost, the first robustness and the first compute cost being greater, respectively, than the second robustness and the second compute cost”

170. Support for this claim element is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
<u>[36.d] wherein the detecting of the target in the image is performed using a first neural network at a first robustness and a first compute cost, and the determining of the three-dimensional relative location of the target in the image comprises incrementally predicting the location of the target in the image using a second neural network at a second robustness and a second compute cost, the first robustness and the first compute cost being greater, respectively, than the second robustness and the second compute cost.</u>	EX2019, ¶ 34 (“In some embodiments, an image is received and a target aerial vehicle is detected in the image. For example, a stream of images captured by one or more cameras of an interceptor aerial vehicle is analyzed using deep learning, neural networks, and/or other machine learning techniques to recognize a target aerial vehicle in the captured image”); EX1001, 3:31-36. EX2019, ¶ 109 (“Deep neural networks (DNN) may be executed to periodically detect objects and distinguish targets”), ¶ 110 (“Once an object is detected in high-resolution mode (i.e. using DNN or manual input) a tracker algorithm takes control and maintains lock on the target. Applying different tracking algorithms and DNN based detections of a target in the video frame provides robustness at a high compute cost. A reduced resource background tracker may incrementally predict the location of a target in the frame with low compute cost and average robustness”); EX1001, 22:3-7 EX2019, ¶ 145 (“processing schemes can be grouped as: (i) High cost (low refresh rate), high robustness algorithm ... (iii) Low cost (high

Claim Element	Support in the Specification
	refresh rate), low robustness algorithms”); EX1001, 27:53-64. EX2019, ¶ 150 (“Processing scheme examples for a group (i) High cost (low refresh rate) – high robustness can include modified tiny You only look once (YOLO) Convolutional Neural Networks (CNN) on 448 pixels input tiles in the frame; a modified SSD (Single Shot Detection) CNN on 300 pixels multi-scale classification; a modified Faster R-CNN (Region Proposal Networks), segmentation analysis of the frame+ classifier for each candidate, etc.”); EX1001, 28:40-47. EX2019, ¶ 151 (“Processing scheme examples for a group (ii) & (iii) can include using SqueezeNet super fast rejection CNN as the validation method on the estimated location produced by the algorithms”), ¶ 152 (“Group (iii) Low-cost – low robustness processing scheme examples can include: extrapolation of location of object from past locations (e.g., no confidence measure (always max), depend on validation method to reject estimation, etc.); SqueezeNet super fast rejection CNN; template matching to the last known object appearance based on past detections, etc.); EX1001, 28:48-51, 28:64-29:3. EX2019, ¶ 113 (“[i]n an example, the set of processing schemes process the video data stream using different resolutions”), ¶ 121 (“Figure 15 illustrates a tracking system 1500 in accordance with one embodiment. One or more components of system 1550 may be utilized in 406 of Figure 4. The tracking system 1500 comprises a cameras 1528 producing multi-camera views 1518 that are input to a processor 1508. The processor operates to filter and de-noise the multi-camera views 1518 to populate a pixel domain 1516. The pixel domain 1516 is divided into nodes (e.g., node 1506, node 1520, node 1514, and node 1512 that are then

Claim Element	Support in the Specification
	analyzed by a high resolution tracker 1502. Output of the high resolution tracker 1502 is input to a fast, low power consumption low resolution tracker 1510. In this example, the node 1506 comprises an anomaly 1522. The high resolution tracker 1502 identifies the anomaly 1522 as a detected object 1524, which is then tracked by the low resolution tracker 1510”), Figure 15; EX1001, 22:39-41, 24:13-27, FIG. 15. <i>See also</i> EX2019, ¶ 50 (“The one or more machine learning models 205 may be configured to implement one or more machine learning algorithms (e.g., support vector machine, soft max classifier, autoencoders, naive bayes, logistic regression, decision trees, random forest, neural network, deep learning, nearest neighbor, etc.)”); EX1001, 7:27-32.

171. Thus, the ’452 App. discloses detecting a target by analyzing one or more images using a machine learning model configured to implement a neural network. The ’452 App. further discloses that a high robustness, high compute-cost neural network, such as DNN, may be used initially to detect a target, and thereafter, the target location may be predicted incrementally using a low robustness, low compute cost technique, such as via extrapolation or template matching, or by using a low resolution tracker and/or a neural network.

Accordingly, the ’452 App. teaches claim element [36.d].

172. In summary, the ’452 App. discloses, and thus, the ’711 patent teaches each and every element of proposed substitute claim 36.

E. Proposed Substitute Claim 37 (Substitute for Claim 20)

- a [37.pre] “A computer program product for performing a flight control operation of a reference aerial vehicle, the computer program product being embodied in a non-transitory computer readable storage medium housed in a reference aerial vehicle and comprising computer instructions for:”*

173. Support for the preamble is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[[20]]37.[pre] A computer program product for performing a flight control operation of a reference aerial vehicle, the computer program product being embodied in a non-transitory computer readable storage medium housed in a reference aerial vehicle and comprising computer instructions for:	EX2019, ¶ 30 (“The invention can be implemented in numerous ways, including as a process; an apparatus; a system; a composition of matter; a computer program product embodied on a computer readable storage medium ; and/or a processor, such as a processor configured to execute instructions stored on and/or provided by a memory coupled to the processor); EX1001, 2:36-41. <i>See supra</i> § (proposed substitute claim 21, preamble [21.pre] (reciting “performing a flight control operation of a reference aerial vehicle”).

174. Thus, the '452 application discloses memory such as a non-transitory storage medium, coupled to a processor on-board a reference UAV, where the non-transitory storage medium includes instructions for the processor. Additionally, substantially similar to the preamble of proposed substitute claim 37, preamble of proposed substitute claim 21 ([21.pre]) recites “performing a flight control operation of a reference aerial vehicle” Therefore, as discussed for [21.pre],

see *supra* § XI.D.1.a, the '452 App. teaches the preamble of proposed substitute claim 37.

b [37.a] “receiving an image captured by an image sensor of the reference aerial vehicle;”

175. Support for this claim element is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[37.a] receiving an image captured by an image sensor of the reference aerial vehicle;	<i>See supra</i> § XI.D.1.b (proposed substitute claim 21, element [21.a]).

176. This claim element is substantially similar to claim element [21.a], which recites “receiving at a processor at the reference aerial vehicle an image captured by an image sensor of the reference aerial vehicle.” Accordingly, the '452 App. teaches claim element [37.a].

c [37.b] “detecting a target in the image including by applying a machine learning model to the image to identify a portion of the image that includes the target;”

177. Support for this claim element is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[37.b] detecting a target in the image including by applying a machine learning model to the image to identify a portion	<i>See supra</i> § XI.D.1.c (proposed substitute claim 21, element [21.b]).

Claim Element	Support in the Specification
of the image that includes the target;	

178. This claim element is substantially similar to claim element [21.b], which recites “detecting at the reference aerial vehicle a target in the image including by applying at the reference aerial vehicle a machine learning model to the image to identify a bounding box outlining a portion of the image that includes detected features of the target.” Accordingly, the ’452 App. teaches claim element [37.b].

d [37.c] “determining a three-dimensional relative location of the target with respect to the reference aerial vehicle based on the image including by determining a distance to the target based at least in part on a size of the target detected within the image; and”

179. Support for this claim element is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[37.c] determining a three-dimensional relative location of the target with respect to the reference aerial vehicle based on the image including by determining a distance to the target based at least in part on a size of the target detected within the image; and	<i>See supra</i> § XI.D.1.d (proposed substitute claim 21, element [21.c]).

180. This claim element is substantially similar to claim element [21.c], which recites “determining at the reference aerial vehicle a three-dimensional relative location of the target with respect to the reference aerial vehicle based on the image including by determining a distance to the target based at least in part on an area of the bounding box of the target detected within the image and on a physical size corresponding to an identified type of the target detected within the image; and.” Accordingly, the ’452 App. teaches claim element [37.c].

e [37.d] “performing the flight control operation based on the three-dimensional relative location of the target with respect to the reference aerial vehicle, wherein performing the flight control operation includes determining a speed adjustment factor based on a magnitude of deviation of a direction of the three-dimensional relative location with respect to a current flight direction of the reference aerial vehicle,”

181. Support for this claim element is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[37.d] performing the flight control operation based on the three-dimensional relative location of the target with respect to the reference aerial vehicle, wherein performing the flight control operation includes determining a speed adjustment factor based on a magnitude of deviation of a direction of the three-	<i>See supra</i> § XI.D.1.e (proposed substitute claim 21, element [21.d]).

Claim Element	Support in the Specification
dimensional relative location with respect to a current flight direction of the reference aerial vehicle[[.], ₂	

182. This claim element is substantially similar to claim element [21.d], which recites “performing at the reference aerial vehicle the flight control operation based on the three-dimensional relative location of the target with respect to the reference aerial vehicle, wherein performing the flight control operation includes determining a speed adjustment factor based on a magnitude of deviation of a direction of the three-dimensional relative location with respect to a current flight direction of the reference aerial vehicle.” Accordingly, the ’452 App. teaches claim element [37.d].

f [37.e1] “wherein the detecting of the target comprises: determining a confidence level for the detection of the target, and”

183. Support for this claim element is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[37.e1] <u>wherein the detecting of the target comprises: determining a confidence level for the detection of the target, and</u>	EX2019, ¶ 141 (“An example aspect includes optimized video processing scheme scheduling. In an example implementation, processing schemes include localization algorithms that process video frames of one or more video data streams. The processing schemes produce a prediction of objects within the video fame, as well as a

Claim Element	Support in the Specification
	confidence number that is a measure of qualify for that prediction”); EX1001, 27:26-32. EX2019, ¶ 146 (“In an example implementation, a set of processing schemes (e.g., algorithms) are examined from group to group, and the process cycles through the processing schemes to produce a detection of an object. According to the example implementations, if the confidence number is higher than an activation number, an action is performed to stop or change a running group (i) and select or switch to group (ii). For example, a processing scheme from the group of (i) High cost (low refresh rate), high robustness algorithm can select a cheaper processing scheme from the group of (ii) Medium cost, medium robustness algorithms. Medium cost algorithms can be run from group (ii) in higher refresh rate, while monitoring the confidence level of the result”), ¶ 147 (“[a]ccording to an example implementation, a voting system is provided that fuses estimations from high confidence results, and validates the result with an independent validation method. If the confidence is below low threshold, falls outside of a range, or the validation method fails, group (i) processing is performed. If the confidence is determined to be high, then group (iii) algorithms can be applied to optimize resources”); EX1001, 27:65-28:18.

184. Thus, the ’452 App. discloses detecting a target by analyzing one or more images using a machine learning model configured to implement a neural network. The ’452 App. further discloses that a high-cost, high robustness but low refresh rate neural network, such as CNN, R-CNN, may be used to detect a target. The ’452 App. also discloses that a medium / low robustness, medium / low cost,

but medium / high refresh rate neural network, such as the SqueezeNet CNN, may be used for subsequent / continuing target detection.

185. I explained above, that the cost of a neural network is typically recognized in terms of the processing load or the number of processing cycles, which relates to the processing time. *See supra* ¶ 73. Thus, a high robustness, high cost neural network generally takes relatively more time for processing an input image compared to that required by a medium / low robustness, medium / low cost neural network. As such, the rate at which a high robustness neural network can process images, i.e., the refresh rate tends to be lower. The opposite is generally true for a low /medium robustness, low / medium cost neural network, which typically has a higher refresh rate than that of a high robustness, high cost neural network. The '452 App. discloses using all these types of neural networks for target detection, and thus teaches claim element [37.e1].

g [37.e2] “using a first neural network having a first robustness and a first refresh rate, or a second neural network having a second robustness and a second refresh rate, the first robustness being greater than the second robustness and the first refresh rate being smaller than the second refresh rate, and”

186. Support for this claim element is found in the '452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[37.e2] <u>using a first neural network having a</u>	EX2019, ¶ 141 (“ In an example implementation, processing schemes include localization algorithms

Claim Element	Support in the Specification
<u>first robustness and a first refresh rate, or a second neural network having a second robustness and a second refresh rate, the first robustness being greater than the second robustness and the first refresh rate being smaller than the second refresh rate, and</u>	that process video frames of one or more video data streams. The processing schemes produce a prediction of objects within the video frame, as well as a confidence number that is a measure of quality for that prediction”); EX1001, 27:27-32. EX2019, ¶ 145 (“For example, processing schemes can be grouped as: (i) High cost (low refresh rate), high robustness algorithm (e.g., processing schemes that produce an object location estimation independent of historical information) ; (ii) Medium cost, medium robustness algorithms ... (iii) Low cost (high refresh rate), low robustness algorithms (e.g., processing schemes that use a known location of the object location estimation and or a fast validation method to validate the estimation)”); EX1001, 27:53-64. EX2019, ¶ 150 (“Processing scheme examples for a group (i) High cost (low refresh rate) – high robustness can include modified tiny You only look once (YOLO) Convolutional Neural Networks (CNN) on 448 pixels input tiles in the frame; a modified SSD (Single Shot Detection) CNN on 300 pixels multi-scale classification; a modified Faster R-CNN (Region Proposal Networks), segmentation analysis of the frame+ classifier for each candidate, etc.”); EX1001, 28:40-47. EX2019, ¶ 151 (“Processing scheme examples for a group (ii) & (iii) can include using SqueezeNet super fast rejection CNN as the validation method on the estimated location produced by the algorithms”); EX1001, 28:48-51. EX2019, ¶ 152 (“Group (iii) Low-cost – low robustness processing scheme examples can include: extrapolation of location of object from past locations (e.g., no confidence measure (always max), depend on validation method to reject estimation, etc.); SqueezeNet super fast rejection

Claim Element	Support in the Specification
	CNN; template matching to the last known object appearance based on past detections, etc.); EX1001, 28:64-29:3. <i>See also</i> EX2019, ¶ 147 (“Different Groups of algorithms (e.g., group (iii) and group (ii)) may be similar and selected based on different secondary factors to optimize local computing resources. For example, group (iii) algorithms may operate like group (ii) with a similar validation method but have secondary factors such as faster and more brittle performance”); EX1001, 28:18-21.

187. Thus, the ’452 App. discloses various “processing schemes” “produce a prediction of objects” also described as “a detection of an object.” The processing schemes include high cost, high robustness, low refreshment rate techniques including neural networks, and low / medium cost, low / medium robustness, high refreshment rate techniques including neural networks. A “confidence number that is a measure of quality of that prediction,” i.e., a measure of quality of the detection of the object, or a “confidence level” is also computed for the different types of processing schemes. Accordingly, the ’452 App. teaches claim element [37.e2].

h [37.e3] “wherein the first neural network is used when the confidence level is below a given threshold and the second neural network is used when the confidence level is above the given threshold.”

188. Support for this claim element is found in the ’452 App. at least at the portions cited below.

Claim Element	Support in the Specification
[37.e3] <u>wherein the first neural network is used when the confidence level is below a given threshold and the second neural network is used when the confidence level is above the given threshold.</u>	EX2019, ¶ 146 (“[i]n an example implementation, a set of processing schemes (e.g., algorithms) are examined from group to group, and the process cycles through the processing schemes to produce a detection of an object. According to the example implementations, if the confidence number is higher than an activation number, an action is performed to stop or change a running group (i) and select or switch to group (ii)”); EX1001, 27:65-28-5. EX2019, ¶ 147 (“[a]ccording to an example implementation, a voting system is provided that fuses estimations from high confidence results, and validates the result with an independent validation method. If the confidence is below low threshold, falls outside of a range, or the validation method fails, group (i) processing is performed. If the confidence is determined to be high, then group (iii) algorithms can be applied to optimize resources”); EX1001, 28:11-18.

189. Thus, the ’452 App. teaches that on the one hand, when a high robustness, low refresh rate neural network is used for target detection, if the confidence level of the detection is above a selected threshold level, subsequent object detection may be performed using a low robustness, high refresh rate neural network. The advantage of this switch is that images can be captured and processed at an increased rate, which can help continued detection and tracking of a moving target.

190. On the other hand, when a low robustness, high refresh rate neural network is used for target detection, if the confidence level is below a selected

threshold level, subsequent object detection may be performed using a high robustness, low refresh rate neural network. The advantage of this switch is that even though the subsequent images can be captured and processed at a decreased rate, a target object in those images can be detected more accurately. This is beneficial, if not necessary, when the target is moving abruptly, suddenly changing direction and or speed. Accordingly, the '452 App. teaches claim element [37.e3].

191. In summary, the '452 App. discloses, and thus, the '711 patent teaches each and every element of proposed substitute claim 37.

192. In light of the foregoing, it is my opinion that each of the proposed substitute claims 21-40 is fully supported by the original disclosure of the '711 patent, and none of the proposed substitute claims adds new subject matter.

XII. PROPOSED SUBSTITUTE CLAIMS ARE PATENTABLE

193. I am informed by counsel and understand that Petitioners “bear[] the burden of persuasion to show, by a preponderance of the evidence, that any proposed substitute claims are unpatentable.” 37 C.F.R. § 42.121(d)(2).

Nevertheless, I discuss below that each of the proposed substitute claims is patentable over the prior art cited in the Grounds asserted this IPR proceeding. I have not been provided with any particular combinations of the cited prior art as allegedly rendering proposed independent substitute claims 21, 36, or 37 obvious.

Therefore, at this time I do not present any opinion about the motivation to combine, or lack thereof, the references that I discuss below.

194. In this IPR, challenged claims 1, 19, and 20 are independent claims. In Ground 1, Petitioners contend that claims 1, 19, and 20 are unpatentable over the combination of Beard and Laufer. Pet. at 10-36. In Grounds 7 and 8, Petitioners contend that claims 1, 19, and 20 are unpatentable over Pierce and the combination of Pierce and Kumar. Pet. at 50-68. In other Grounds alleging unpatentability of the dependent claims, Petitioners cite Khan, Kumar, Malecki, Sahasrabudhe, and Hogasten. These references in the context of the limitations of the proposed substitute claims are discussed below.

1. Proposed substitute claim 21

a “Applying at the reference aerial vehicle a machine learning model to the image”

195. Proposed substitute claim 21 recites “detecting at the reference aerial vehicle a target in the image including by applying at the reference aerial vehicle a machine learning model to the image” to determine a “bounding box of the target” and “type of the target.” Beard is silent on machine learning models or neural networks. See Pet. 15; EX1003, ¶¶ 117-118; *see generally*, EX1009.

196. Laufer appears to describe the use of machine learning / a neural network for detecting targets. See Pet. 15; EX1003, ¶ 118; EX1010, ¶ 31. Laufer states:

Drone identification module 220 permits central controller 115 to positively detect targets as threats. **Drone identification module 220** can use video or image data from fixed camera 130 and/or cameras mounted on interceptor aircraft 140A-140B and/or data from radars 110A-110C to **determine whether a detected target exhibits characteristics that would indicate it was a threat. Machine learning algorithms**, for example Deep Convolutional Neural Network architectures such as those available from OpenCV or TensorFlow, **can be used to classify** whether a target is a threat or not.

EX1010, ¶ 31, FIG. 2.

197. Thus, in Laufer’s system, it is the drone identification module 220 that may apply a machine learning model / neural network. But, in Laufer’s system, the drone identification module is part of the central controller 115. *Id.* As noted earlier, Laufer’s “central controller 115 is connected to stationary components of interdiction system 100 by a **wired connection**,” and “can be connected to interceptor aircraft 140A-140B through a wireless connection.” *Id.* ¶ 30.

Therefore, Laufer’s central controller 115 is not a part of and cannot be a part of the UAV disclosed by Laufer. *See supra* ¶ 91. As such, Laufer does not teach or suggest “applying at the reference aerial vehicle a machine learning model to the image,” as proposed substitute claim 21 recites.

198. Pierce discloses “a drone system 600” that “includes a processor 601, memory 603.” EX1005, ¶ 42, FIG. 6. Pierce’s “drone system 600 may be drone

102.” *Id.* Moreover, “the **drone system 600** uses memory 603 to store data and program instructions for **operations including** training a neural network, **object detection by a neural network**, and distance and velocity estimation.” *Id.*, ¶ 44.

199. Pierce does not state that “object detection by a neural network” is performed on-board a drone. Pierce also does not suggest such an implementation, and instead, discloses a drone system in which the neural network based object detection is performed by a “streaming server” that is separate from the drone. Specifically, Pierce states that “various elements of drone system 600 may correspond to **separate components**, including drone 102, **a server**, a controller, etc.,” and that the “drone system 600 ... includes a processor 601, memory 603, an **interface 611**, ... and may operate as a **streaming server**.” *Id.* ¶ 42.

200. With reference to its FIG. 5, Pierce discloses “a neural network system 500” that also “includes a processor 501, memory 503, an interface 511” and that “operates as a **streaming server**.” *Id.*, ¶ 38, FIG. 5. Thus, the embodiments of the drone system 600 that perform neural network based object detection and operate as a streaming server, include a server (such as the neural network system 500), that is a “separate component[]” from the drone and that implements a neural network.

201. Around the time of filing of Pierce and of the ’452 App. a POSITA would have known that a “streaming server” communicates with other entities via

a network, such as the Internet. *See* EX2020 (Merriam Webster Dictionary archived on November 23, 2016) (“playing continuously as data is sent to a computer over the Internet”); EX2021 (Collins English Dictionary archived on January 26, 2018) (“Streaming is a method of transmitting data from the Internet directly to a user's computer screen without the need to download it”).

202. Consistent with the operation of the drone system 600 as a “streaming server,” which involves communication via a network, Pierce discloses that the drone system 600 includes “an interface 611” that “is typically configured to send and receive data packets or data segments over a network.” EX1005, ¶ 42; *see id.* ¶ 38 (the “interface 511 is typically configured to send and receive data packets or data segments over a network”). “Particular examples” of the interfaces 511 and 611 include “Ethernet interfaces, frame relay interfaces, cable interfaces, DSL interfaces.” EX1005, ¶¶ 39, 43. Although all of these are “examples,” all of these interfaces are wired interfaces that only a separate server, and not a processor on-board a UAV, can support.

203. Additionally, Pierce’s claim 11 recites a “system” having “a drone” and “one or more processors” and “memory” that stores “instructions to ... determine angular velocity and a linear velocity for the drone.” Claim 11 does not recite the processors and the memory as part of the drone. As such, in light of the Pierce’s disclosure, a POSITA would have understood that a drone system 600, that

may operate as a streaming server, is not provided and cannot be provided at a UAV. Accordingly, Pierce does not teach or suggest “applying at the reference aerial vehicle a machine learning model to the image,” as proposed substitute claim 21 recites.

204. Like Pierce, Kumar also discloses “a neural network system 400.” EX1008, ¶ 35, Figure 4; EX1007, ¶ 40, FIG. 4. Like Pierce’s neural network system 500 and drone system 600, Kumar’s neural network system 400 “operates as a **streaming server**” and has an “interface 411 [that] is typically configured to send and receive data packets or data segments over a network.” EX1008, ¶ 35; EX1007, ¶ 40. Further as in Pierce, examples of Kumar’s interface also include wired interfaces such as “Ethernet interfaces, frame relay interfaces, cable interfaces, DSL interfaces.” EX1008, ¶ 36; EX1007, ¶ 41. Finally, Kumar does not disclose a drone system. Therefore, Pierce does not teach or suggest “applying at the reference aerial vehicle a machine learning model to the image,” as proposed substitute claim 21 recites.

205. Khan, for its part, appears to disclose “a computer implemented method for determining a vehicle type of a vehicle detected in an image.” EX1021, ¶ 10. Khan also describes an “unmanned aerial vehicle (UAV) 100 configured to acquire a plurality of three-dimensional (3D) images of one or more vehicles 102 in a scene 104.” *Id.* ¶ 37, FIGS. 1A, 1B. Khan further discloses “an

exemplary digital processing system 112 for detecting and classifying types of vehicle models in aerial imagery captured by one or more image capturing devices 106 associated with the UAV 100.” *Id.* ¶ 39, FIG. 2.

206. Khan further states:

[T]he system 112 receives digitized video from one or more 3D image capturing devices 106 (e.g., cameras), which may be rigidly mounted on the **aerial platform 107**. The system may include a plurality of on-board sensors 108 described hereinabove. The system 112 may include an on-board computing platform 114, or the **computer platform 114 may be located on the ground** to which images and telemetry received by the on-board sensors 108 may be **transmitted by a radio transmitter 116**.

Id. ¶ 39, FIG. 2. Khan also states that “the digitized video or still images may be received from a network 120, such as the Internet.” *Id.* The aerial platform 107 can be a “UAV platform 107.” *Id.* ¶ 42, FIGS. 4A, 4B. Thus, in Khan’s system, the computer platform is not at a UAV or an aerial platform.

207. Khan also discloses one or more “linear classifier[s], preferably [] support vector machine classifier[s] (SVM),” for detecting the “specific vehicle type” of a “detected vehicle 702 in [a] captured image 700.” Khan does not state that the classifier(s) are provided at the aerial platform or at the UAV. To the extent Khan’s classifiers / SVMs are implemented by the computing platform, as noted above, the computing platform is not at a UAV or at any other aerial platform. As

such, Khan does not teach or suggest “applying at the reference aerial vehicle a machine learning model to the image,” as proposed substitute claim 21 recites.

208. Malecki appears to disclose “determining the three dimensional orientation and position [of an object] based on a two dimension representation of the object.” EX1024, ¶ 30. Sahasrabudhe appears to disclose “a self-contained, autonomous formation flying system 10.” EX1025, ¶ 11, FIG. 1. Hogasten appears to disclose an “object detection system 100” having “an object detection device 102” that includes “a distance sensor 106 and a thermal sensor 104.” EX1022, ¶ 15, Fig. 1; EX1023, ¶ 14. None of Malecki, Sahasrabudhe, and Hogasten mentions machine learning or neural networks.

209. As such, none of references that Petitioners cite, i.e., Beard, Laufer, Pierce, Kumar, Khan, Malecki, Sahasrabudhe, and Hogasten, individually or in combination with one or more of the other cited references, teaches or suggests “applying at the reference aerial vehicle a machine learning model to the image,” as proposed substitute claim 21 recites. Proposed substitute claim 21 is therefore patentable at least for the above-discussed reason.

2. Proposed Substitute Claim 24.

210. Proposed substitute claim 24 depends from proposed substitute claim 21, and is therefore patentable for that reason alone. Moreover, proposed substitute claim 24 recites “applying the machine learning model to the image to identify a

specific type of the target.” Each of Beard, Laufer, Pierce, Malecki, Sahasrabudhe, and Hogasten is silent on using a type of a target. Kumar describes used “the known physical box size of [a] type of object.” EX1008, ¶¶ 19, 32, FIG. 3A. But Kumar does not describe identifying the type of the object.

211. As discussed above, Khan discloses using one or more classifiers / SVMs to determine a specific vehicle type. But, as I explained above, Khan’s classifiers / SVMs may be implemented by a computing platform that is not at a UAV or at any other aerial platform. *See supra* ¶¶ 205-207. As recited in claim element [21.b], “the machine learning model” is applied “at the reference aerial vehicle,” which Khan and Beard, Laufer, Pierce, Kumar, Malecki, Sahasrabudhe, and Hogasten do not teach or suggest. Therefore, none of references that Petitioners cite, individually or in combination with one or more of the other cited references, teaches or suggests the limitation that proposed substitute claim 24 recites. Therefore, proposed substitute claim 24 is patentable.

3. Proposed Substitute Claim 36

212. Proposed substitute claim 36 recites “wherein the detecting of the target in the image is performed using a neural network at a first robustness and a first compute cost, and the determining of the three-dimensional relative location of the target in the image comprises incrementally predicting the location of the target in the image at a second robustness and a second compute cost, the first

robustness and the first compute cost being greater, respectively, than the second robustness and the second compute cost.”

213. As discussed above for proposed substitute claim 11, Beard, Malecki, Sahasrabudhe, and Hogasten are silent on using neural networks. Kumar, Malecki, Sahasrabudhe, and Hogasten are silent on predicting the location of a target. Beard describes “predictively analyz[ing] the future position of future direction of [a target] skier,” but uses “data received from [the skier’s] smartphone” to this end. *See* EX1009, 6:57-7:6, FIG. 3. Pierce describes that “including the target’s linear velocity in determining the linear velocity 411 of the drone allows the system to predict the moving target’s movement and velocity.” EX1005, ¶ 36. Laufer describes that the “[c]entral controller 115 can use interception module 420 to determine the location at which the interceptor aircraft dynamics model and the target model predict the target and the interceptor aircraft will intersect.” EX1010, ¶ 39, *see id.* ¶ 44 (describing prediction using an optimizer module), FIGS. 4, 5.

214. None of the references that Petitioners cite discloses, however, using both a neural network for target detection, and incrementally predicting target location, where the robustness and compute cost of the incremental predictions are lower, respectively, than the robustness and compute cost of target detection using a neural network. Therefore, none of the references that Petitioners cite, individually or in combination with one or more of the other cited references,

teaches or suggests the above-stated limitation that proposed substitute claim 36 recites. Proposed substitute claim 36 is therefore patentable at least for that reason.

4. Proposed Substitute Claim 37

- a “Using a first neural network having a first robustness and a first refresh rate, or a second neural network having a second robustness and a second refresh rate, the first robustness being greater than the second robustness and the first refresh rate being smaller than the second refresh rate”*

215. None of references that Petitioners cite mentions two different neural networks having different levels of robustness and/or different refresh rates.

Therefore, none of references that Petitioners cite, individually or in combination with one or more of the other cited references, teaches or suggests the above-stated limitation that proposed substitute claim 37 recites. Proposed substitute claim 37 is therefore patentable at least for that reason.

- b The first neural network is used when the confidence level is below a given threshold and the second neural network is used when the confidence level is above the given threshold*

216. None of references that Petitioners cite discloses switching between two different neural networks having different levels of robustness and/or different refresh rates based on a confidence level. Khan describes using several classifiers / SVMs for detecting the type of a vehicle, and then selecting the “best” vehicle type “based on a confidence value[] employed in each SVM that ‘fired,’ i.e., detected the vehicle type. EX1021, ¶ 62. Khan does not teach or suggest, however,

choosing between and using one or the other classifiers based on their confidence values.

217. Therefore, none of references that Petitioners cite, individually or in combination with one or more of the other cited references, teaches or suggests the above-stated limitation that proposed substitute claim 37 recites. Proposed substitute claim 37 is therefore patentable at least for this reason, as well.

XIII. CONCLUSION

218. For the foregoing reasons, it is my opinion that the challenged claim 12, and proposed substitute claims 21-37 are patentable.

219. I currently hold the opinions that I have expressed in this declaration. My analysis may continue, however, as I may acquire or receive additional information or insights that may result in revised or supplemental observations or opinions.

220. I understand this declaration may be used as evidence in the instant IPR proceeding the PTAB.

221. I declare that all statements made herein on 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 or Title 18 of the United State Code, and that such willful false statements may jeopardize the validity of the '711 patent.

222. I declare under penalty of perjury that the foregoing is true and correct.

Dated: December 19, 2025

Respectfully submitted,

A handwritten signature in black ink, appearing to be 'N. Papanikolopoulos', written over a light gray rectangular background.

Dr. Nikolaos Papanikolopoulos