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LASER SPALLATION TECHNOLOGIES, LLC

**IN THE UNITED STATES DISTRICT COURT
FOR THE CENTRAL DISTRICT OF CALIFORNIA
WESTERN DIVISION**

LASER SPALLATION
TECHNOLOGIES, LLC,
a California company

Plaintiff,

v.

THE BOEING COMPANY, a
Delaware corporation,

Defendant.

Case No. 2:23-cv-02294-AB-SK

**DECLARATION OF VIJAY GUPTA
IN SUPPORT OF PLAINTIFF'S
SECOND AMENDED COMPLAINT**

Judge: Hon. André Birotte Jr.

1 1. I, Vijay Gupta, Ph.D., declare as follows:

2 2. I submit this declaration in support of the Second Amended Complaint of
3 Plaintiff, Laser Spallation Technologies, LLC (“LST”), against Defendant, The Boeing
4 Company (“Boeing”), in the above-captioned action. The facts stated herein are true
5 based on my own personal knowledge or knowledge obtained through my employment
6 at the University of California Los Angeles (“UCLA”), conversations with other
7 persons, and my review of personal records and records kept as part of my
8 employment by UCLA. If called upon to testify, I could and would competently
9 testify thereto.

10 3. I am currently a Full Tenured Distinguished Professor of Mechanical and
11 Aerospace Engineering at UCLA. I also hold appointments as a Full Professor in the
12 Materials Science and Engineering Department and Biomedical Engineering
13 Department at UCLA. I have a Ph.D. in Mechanical Engineering and an M.S. in
14 Structural Engineering, both from the Massachusetts Institute of Technology (“MIT”).
15 After finishing my Ph.D. in 1990, I joined the faculty at Dartmouth College as an
16 Assistant Professor and was promoted to the rank of Full Professor, with tenure, at
17 UCLA in 1995, directly from the Assistant Professor rank, without undergoing the
18 usual Associate Professor step. At age 31, I became the youngest Full Professor with
19 tenure in the United States, only 5 years after receiving my Ph.D. degree.

20 4. In April 2018, I was given the status of “Distinguished Professor” by the
21 Regents of the University of California, which is the highest rank bestowed on a Full
22 Professor in the University of California System.

23 5. My research has covered a wide range of areas, including interface
24 science and engineering, composite materials, aircraft structures, applied mechanics,
25 fracture mechanics, mechanical engineering design, manufacturing, and
26 biomechanics—both experimentally as well as through mechanistic computer modeling.
27 I am widely acknowledged as the leading experimentalist in the field of solid
28

1 mechanics, notably in the areas of mechanical characterization of joints and interfaces,
2 and mechanical behavior and reliability of aerospace structures made using composite
3 materials, where I have made sustained and pioneering contributions. My research has
4 been widely disseminated in these areas, with over 150 papers published in leading
5 technical journals, conference proceedings and books. I have also given over 200
6 principal keynote lectures in governmental agencies, companies, and national and
7 international conferences and symposia in nearly all industrialized countries. I also
8 hold four United States Patents, with several others pending, with one widely used in
9 the semiconductor industry.

10 6. Measurement and control of the tensile strength of an interface or a joint
11 between two different materials is key to developing reliable components in a variety
12 of industries such as aircraft engines, paint, microelectronics, aerospace structures, and
13 civil construction. My group is best known for developing novel techniques to
14 measure the tensile strength of joints and interfaces. Notable among these is a laser
15 spallation experiment that uses a laser-generated stress wave to pry off an interface.
16 The work on this technique started as part of my Ph.D. thesis at MIT between 1985
17 and 1989, and a commercial version of this tool, with additional features, was
18 developed in 1992 during my tenure at Dartmouth College. This major development
19 in the field of adhesion science and technology was recognized by the U.S. Patent and
20 Trademark Office by granting a U.S. Patent No. 5,438,402 (“the ’402 Patent”). This
21 technique has been used by virtually all major semiconductor companies in the world
22 for characterization of adhesion in devices and packages. It has been transferred to or
23 used for product development in Intel Corporation, Texas Instruments, Hitachi,
24 Freescale Semiconductor, On Semiconductor, and Dow Corning Corporation. This
25 technology has also been widely used in other industrial sectors, such as, automobile
26 (Ford, GM, Delco), television (LG Gould), biomedical (Baxter Corporation), aircraft
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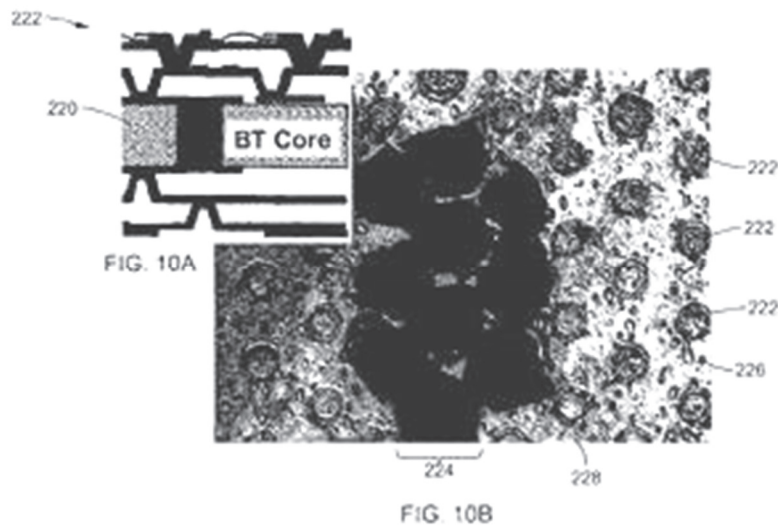
1 engines (Pratt and Whitney, Westinghouse Corporation), paint (Du Pont, Boeing), and
2 Dentistry.

3 7. In the late 1990s, the aerospace industry had the need to test composite
4 joints which required higher stress wave amplitudes of the interrogating stress pulse in
5 the laser spallation tool. At the same time, the microelectronics industry was
6 manufacturing high density nanoscale chips and packages and needed to test the
7 adhesion properties in such nanoscale structures.

8 8. I recognized these needs in the industry, and I worked to develop a
9 method and apparatus that modified the stress wave profiles of the '402 Patent by
10 using a glass element that resulted in sharper stress wave profiles and much higher
11 interface stress amplitudes as needed to test nanoscale structures and composite joints,
12 especially those between thicker composite sections.

13 9. I collaborated with Vassilli Kireev on these subjects, and our work led to
14 the issuance of U.S. Patent No. 7,487,684 ("the '684 Patent"), which is directed to an
15 apparatus and method for (1) generating a tensile force across an interface between two
16 materials using a laser pulse and a glass element, and (2) separating the interface, if
17 desired, by controllably increasing the laser energy.

10. The '684 Patent builds upon the '402 Patent in that it uses a "glass element" to shape the stress wave which in turn results in the generation of a much higher tensile force at the interface (compared to the method claimed in the '402 Patent) even when using a low energy laser pulse. The term "glass element" in the '684 Patent is not limited to silica glasses, but rather the term is used in the patent to describe materials that result in modifying the stress wave profile when it transmits through their thickness. The '684 Patent is conveniently practiced by placing the glass element in the path of the travelling compression or tension wave prior to the arrival of the latter at the bonded joint in a manner so as to propagate and modify a stress wave to the coating/substrate interface to generate a tensile stress.



11. The '684 Patent specifically discusses (at column 11, lines 21-43) the application of the glass modified stress waves for testing and separating composite joints. Figure 10A of the '684 Patent, reproduced above, shows a multilayer plastic substrate with a BT core (a fiber-reinforced epoxy laminate). The compressive stress wave was generated on the top side of this laminate and made to propagate through its entire thickness. The compression stress wave reflected into a tensile wave from its lower free surface and upon its return journey separated the solder joint. It is

1 noteworthy that the area around the solder joint was also separated, which is
 2 essentially a composite laminate that is epoxy-bonded to the BT composite. In fact,
 3 the '684 Patent discusses how, by increasing the laser energy, the area below the solder
 4 joint can also be separated. This separated area is a bonded joint. The '684 Patent thus
 5 teaches how an epoxy joint can be tested using the glass-modified stress wave.

6 Citations from the '684 Patent specification in support of this are provided below:

- 7 • *“Physical illustration of the system of FIG. 9A is demonstrated on a multilayer*
 8 *plastic substrate 220 having a cross-section as shown in the FIG. 10A. The view*
 9 *of FIG. 10B of the top layer shows lead bumps 222 that are used for electrical*
 10 *contacts allowing the Si device to communicate with the substrate circuitry. A*
 11 *laser was impinged onto the undersurface of the plastic substrate 220 in*
 12 *accordance with the present invention to launch the stress wave towards the top*
 13 *layer of the substrate. The stress wave separated the lead bumps 222 and these*
 14 *separated bumps were caught on a flexible plastic tape 226 as shown in FIG.*
 15 *10B.” (Column 11, lines 21-31)*
- 16 • *“It was additionally noted that as the laser energy was increased, separation*
 17 *below the lead bump areas was also accomplished. Thus, in such cases, the lead*
 18 *bumps 222 along with their underlying film were pulled free from the substrate*
 19 *220 and caught on the plastic tape 226. The dark region 224 in FIG.10A is the*
 20 *layer that was below the bumps, which now appears on the very top of the flexible*
 21 *tape substrate 226. FIG.11 shows a focused view of the separated lead bumps in*
 22 *their entirety.” (Column 11, lines 34-41)*

23 12. On March 16, 2010, Boeing presented its roadmap to certify adhesive
 24 joints in its aircraft structures at The Center of Excellence for Advanced Materials in
 25 Transport Aircraft Structures (AMTAS) at the University of Washington, Seattle, WA.
 26 Boeing delivered a presentation entitled, “Boeing’s Certifiable Primary Structural
 27 Bonding Initiative.” Slide No. 3 of the presentation indicates the view of Boeing’s
 28

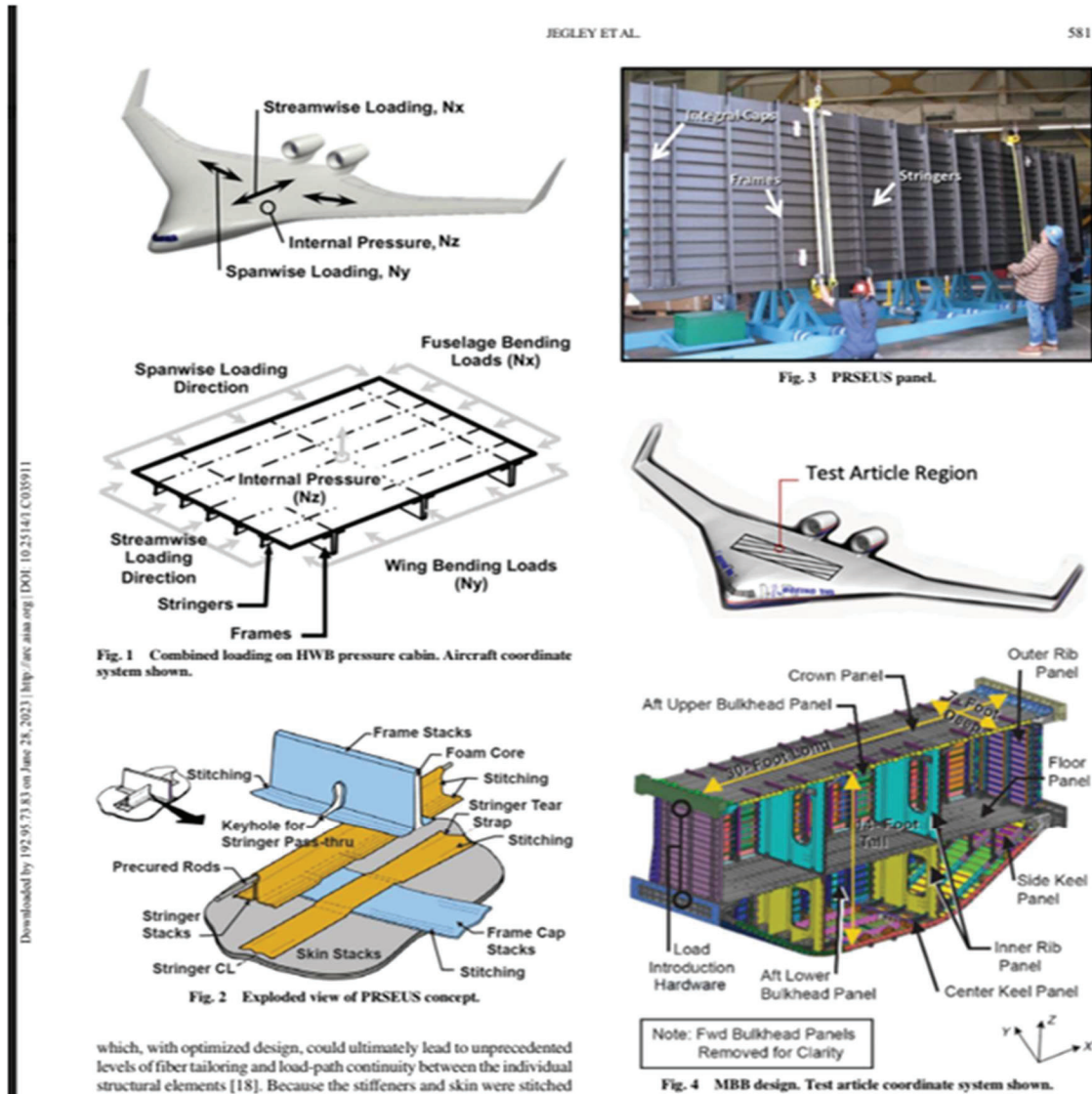
1 engineers that a comprehensive certification approach for bonded structures requires
2 both “Advance Design and Analysis” and use of an “Advance NDE Techniques
3 LBID.” The slide also displays the geometry of a stringer, results from a stress
4 analysis inside the stinger geometry, and the method of Laser Bond Inspection
5 (“LBI”).

6 13. Slide No. 4 from the same Boeing presentation shows the stringer
7 geometry and frame elements that run orthogonal to the stringers. The stress analysis is
8 performed by using the Finite Element Method, and it identifies significant weak bond
9 regions, such as at the joints between aircraft skin and the stringers and ribs. As noted
10 by the Boeing engineers, stress analysis is integral to the overall bond certification
11 process, as it tells them where to monitor and perform the bond inspection by using the
12 ’684 Patent’s invention.

13 14. I understand that Boeing has a testing facility in Huntington Beach,
14 California, and that Boeing’s engineers at that facility have conducted stress analysis
15 of the entire aircraft structure, including stringers and frame elements that are used to
16 stiffen the composite fuselage skin.

17 15. Publications by Boeing engineers show Boeing testing activities in
18 Huntington Beach began as early as 2008 and have continued at least until 2021.
19 These publications include, “*Structural Response of a Stitched Composite Hybrid Wing*
20 *Body Center Section*,” Jegley et al., Journal of Aircraft, Vol. 58, No. 3, May-June
21 2021; and “*Analysis of a Hybrid Wing Body Center Section Test Article*,” Wu et al.,
22 54th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials
23 Conference, April 8-11, 2013. My review of these papers confirms that Boeing
24 engineers identified areas that are most prone to adhesive failure and would therefore
25 require monitoring during servicing of the aircraft. Areas where highest out-of-plane
26 stress and strains occur are where the stringers join the aircraft skin and also between
27 the frame stacks or ribs and the skin or where they cross the stringers. Figure 2 from the
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Boeing papers shows the schematic of a stringer, fuselage skin, and a frame stack, while Figure 3 from the same papers show an actual PRSEUS panel constructed by using these basic elements. PRSEUS stands for Pultruded Rod Stitched Efficient Unitized Structure and is a panel designed to minimize stresses that arise due to the non-circular fuselage geometry of the wide body aircraft.

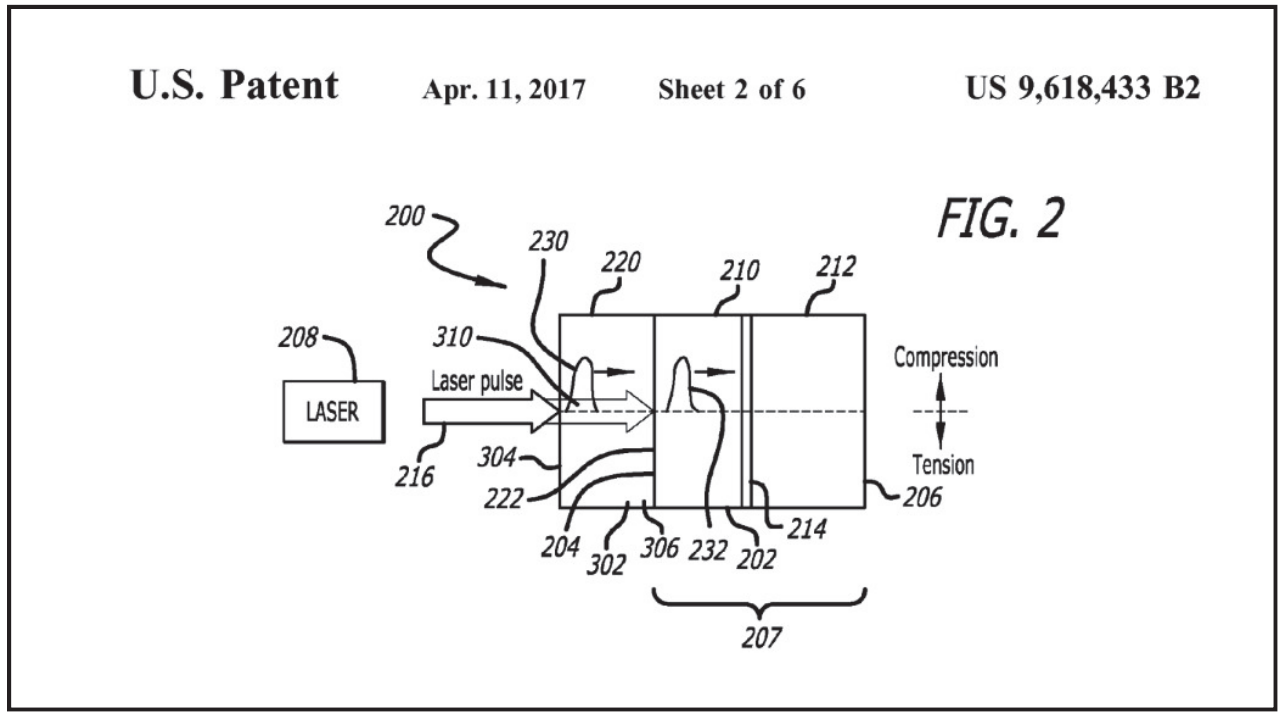


16. Since the time the '684 Patent was granted, Boeing has focused on adopting technologies to allow it to more effectively evaluate the strength of bonds with lasers using tensile stresses. For example, Boeing's U.S. Patent No. 9,618,433

1 (“the Boeing ’433 Patent”), entitled “Method for controlling tensile stress during
2 evaluation of a bond between structures,” with named inventors Kevin R. Housen and
3 William J. Sweet, focuses on testing such bonds. The application for the Boeing ’433
4 Patent was filed in 2014, and Boeing applied for it as “The Boeing Company, Seal
5 Beach, CA (US),” indicating that Boeing applied for that patent while focused on
6 testing bonds with tensile stresses at its Seal Beach facility. I also understand that the
7 Patent Examiner who reviewed the application for the Boeing ’433 Patent cited the
8 application for the ’684 Patent as prior art and rejected the Boeing application because
9 it was so similar to what was disclosed in the application for the ’684 Patent.

10 17. The Boeing ’433 Patent deals with the inspection of the composite joints
11 by use of laser-generated stress waves that are modified by use of a transparent delay
12 element that is identical in structure and function to the glass element taught by my
13 ’684 Patent. I have provided an element-by-element analysis for Claim 13 of my
14 earlier ’684 Patent to show that each and every step of this method claim is identically
15 disclosed in the Boeing ’433 Patent. I understand that the focus of this declaration is
16 not for the Court to decide the infringement issues, but rather to demonstrate Boeing’s
17 activities related to the ’684 Patent are being conducted by Boeing at its facilities
18 located in Southern California. To assist the Court, I have provided an element-by-
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element analysis for Claim 13 of the '684 Patent below. For ease of comparison, I have reproduced Figure 2 from the Boeing '433 Patent below.



18. Claim 13 of the '684 Patent recites:

A method for separating a coating from a substrate, the substrate having a first side and a second side transversely disposed in a first axis, the coating applied to the first side of the substrate such that the coating and substrate are axially spaced along the first axis in intimate facing contact to form a coating/substrate interface, the method comprising:

positioning a glass element along the first axis on the second side of the substrate;

directing a laser pulse in the first axis at the glass element;

propagating a stress wave through the glass element to

1 *the coating/substrate interface to generate a tensile force*
 2 *between the substrate and the coating; and*
 3 *separating the coating from the substrate as a result of*
 4 *the stress wave-generated tensile force.*

5 19. The claim element,

6 *“A method for separating a coating from a substrate, the*
 7 *substrate having a first side and a second side transversely*
 8 *disposed in a first axis, the coating applied to the first side of*
 9 *the substrate such that the coating and substrate are axially*
 10 *spaced along the first axis in intimate facing contact to form*
 11 *a coating/substrate interface, the method comprising,”*

12 appears to be met by the description of the Boeing '433 Patent, as it discloses a bond
 13 214 between two composite substrates 210 and 212, each having first and second sides
 14 (204, 206, 207), and are disposed along a first axis. The two composite substrates are
 15 in intimate facing contact with each other and form an adhesive interface or a bond
 16 214. Substrate 212 is adhesively joined to the first side of the substrate 210.

17 20. The claim element, *“positioning a glass element along the first axis on the*
 18 *second side of the substrate;”* appears to be met by the Boeing '433 Patent as it
 19 discloses what it calls a “delay element 220” and positions it along the first axis on the
 20 second side of the substrate 210 to form an interface 222. The Boeing '433 Patent
 21 describes the “delay element” to be made using transparent glassy materials.

22 21. The glass element in the '684 Patent is defined as an element that
 23 modifies the profile of the initial laser generated stress wave when it traverses through
 24 the glass element prior to reaching the test interface, which in the Boeing '433 Patent
 25 is the bond 214. Acrylic and polycarbonate are some of the examples of the delay
 26 element provided in the Boeing '433 Patent. The structure of these materials would
 27 modify the stress wave 230 as it traverses through the delay component 220. Even
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1 when using other delay elements such as quartz and sapphire that are disclosed in the
2 Boeing '433 Patent, the profile of the 230 wave will change depending upon its initial
3 amplitude as discussed in the '684 Patent. The Boeing '433 Patent teaches that the
4 amplitude of this initial stress wave that traverses through the delay element can be
5 changed (modified) by the user by changing the density of the laser-absorbing pixel
6 pattern on the front face of the glass element (Column 6, ll. 20-25):

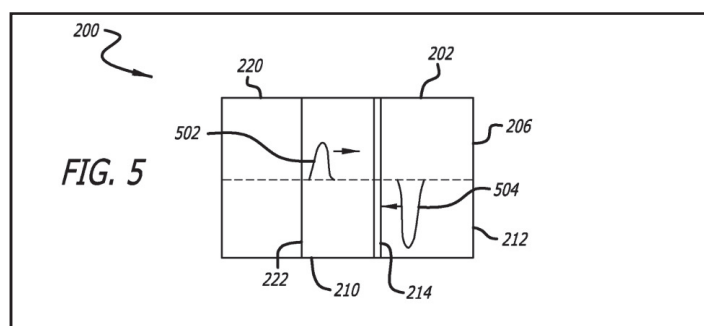
7 “The magnitude of the compression waves generated at the
8 front face 304 relative to that of the back face 306 may be
9 controlled, for example, by adjusting the density of the pixel
10 pattern. The back face 306 in this example may be coated with
11 a solid layer or material, for example, a solid layer of paint,
12 to absorb the remaining portion of laser light.”

13 22. As described in details in the Boeing '433 Patent, this stress wave 230
14 combines with the stress wave 402 to form a stress wave 502, which eventually will
15 arrive at the joint 214 after reflecting from the free surface of the bonded assembly, to
16 generate a tensile stress. It is noteworthy that even the profile of the initial stress wave
17 232 which is generated in the substrate 210 by absorption of the laser energy on the
18 back surface 306 of the glass element or at the interface 222 will be modified by the
19 glass element in the way taught by the '684 Patent. As explained in details in the
20 Boeing '433 Patent, this wave controls the profile and amplitude of the tension wave
21 504 which eventually generates a tensile force at the joint 214 and leads to its
22 separation if its deteriorated strength falls below the Boeing-set proof strength level for
23 the safe operation of its aircraft.

24 23. There are other locations where the '684 Patent's glass element may be
25 present and function as set forth in the claims, such as when Boeing uses glass fiber
26 composites and epoxies to bond the two composite substrates.

24. The claim element “*directing a laser pulse in the first axis at the glass element,*” is present and demonstrated in Figure 2 of the Boeing ’433 Patent by a big arrow with “laser pulse” written on top of it.

25. The claim element, “*propagating a stress wave through the glass element to the coating/substrate interface to generate a tensile force between the substrate and the coating,*” is demonstrated in Figures 2, 4-7, of the Boeing ’433 Patent. The specification provides details on how the initial compression stress waves 230 and 232 propagate through the delay element and bonded composite substrate assembly and get divided at various material interfaces to ultimately form a tension wave 504 (see Figure 5 of the Boeing ’433 Patent, reproduced below) to generate the tensile force at the joint 214.



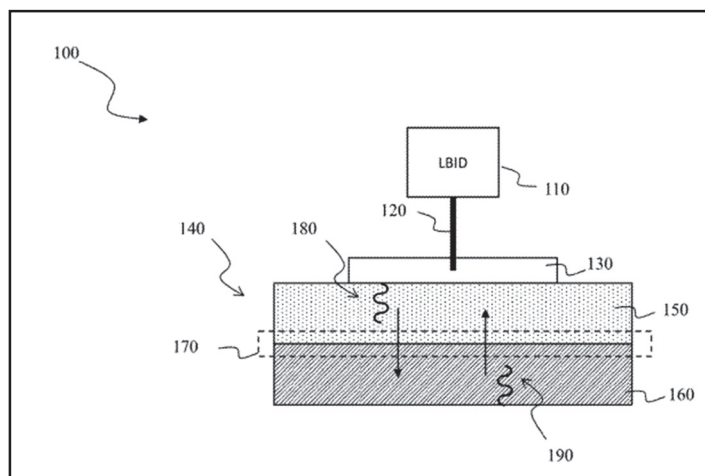
26. The claim element, “*separating the coating from the substrate as a result of the stress wave-generated tensile force,*” appears to be met as soon as a weak bond or a kissing bond is broken in Boeing’s use of the invention of the Boeing ’433 Patent, as the strength of the deteriorated joint falls below the proof strength level that has been predetermined by Boeing as the minimum strength needed at the joint for the safe operation of its aircraft. To set the laser energy corresponding to a specified stress level, Boeing has to carryout strength measurements, each of which results in the failure of the bond, and therefore appears to meet this claim element.

27. In addition to Claim 13, the following dependent claims appear to be met by the disclosures in the Boeing ’433 Patent for all of the foregoing reasons:

- 1 • 14. A method as recited in claim 13, wherein directing a laser pulse in the
- 2 first axis comprises directing a Nd-Yag laser beam in the first axis.
- 3 • 15. A method as recited in claim 13, wherein propagating a stress wave
- 4 comprises propagating a stress wave having a length ranging from
- 5 approximately 5 nanoseconds to approximately 1 microsecond.
- 6 • 17. A method as recited in claim 15, wherein the stress wave is configured
- 7 to separate a coating having a thickness less than approximately 0.5 μm .
- 8 • 18. A method as recited in claim 15, wherein positioning a glass element
- 9 along the first axis comprises bonding the glass element to the second side
- 10 of the substrate.
- 11 ○ This claim element appears to be met when the glass element is in
- 12 the form of a glass laminate or an epoxy to bond the two composite
- 13 substrates.
- 14 • 19. A method as recited in claim 13, wherein the glass element comprises
- 15 one of the following: Pyrex, sodalime, quartz, or borosilicate.
- 16 • 20. A method as recited in claim 19, wherein the glass element has a
- 17 thickness ranging from approximately 0.1 mm to approximately 5 mm.
- 18 ○ The epoxy thickness, glass ply thickness, and optical windows and
- 19 glass confining plates fall in this thickness range.
- 20 • 21. A method as recited in claim 13, further comprising positioning a
- 21 constraining element adjacent to a free side of the glass element.
- 22 • 22. A method as recited in claim 21, further comprising:
- 23 coating an energy absorbing layer on the free side of the glass
- 24 element between the constraining layer and the glass element;
- 25 wherein directing a laser pulse in the first axis comprises
- 26 directing the laser pulse the energy absorbing layer coated on the
- 27 glass element.

- 23. A method as recited in claim 13, wherein the stress generated by the stress wave at the coating/substrate interface exceeds approximately 1.0 GPa.
- 24. A method as recited in claim 23, wherein the stress generated by the stress wave at the coating/substrate interface exceeds approximately 2.0 GPa.

28. I have also reviewed and analyzed United States Patent No. 9,995,670 (“the Boeing ’670 Patent”) entitled, “Method of Controlling a Laser Bond Inspection System,” with named inventors Morteza Safai and Gary E. Georgeson. The applicant of this patent is listed as “The Boeing Company, Huntington Beach, CA.” On the face of this patent, in its Abstract, it says “A method of laser bond inspection is provided.” The Laser Bond Inspection Device or LBID is shown in Figure 1 of the patent which I have reproduced below:



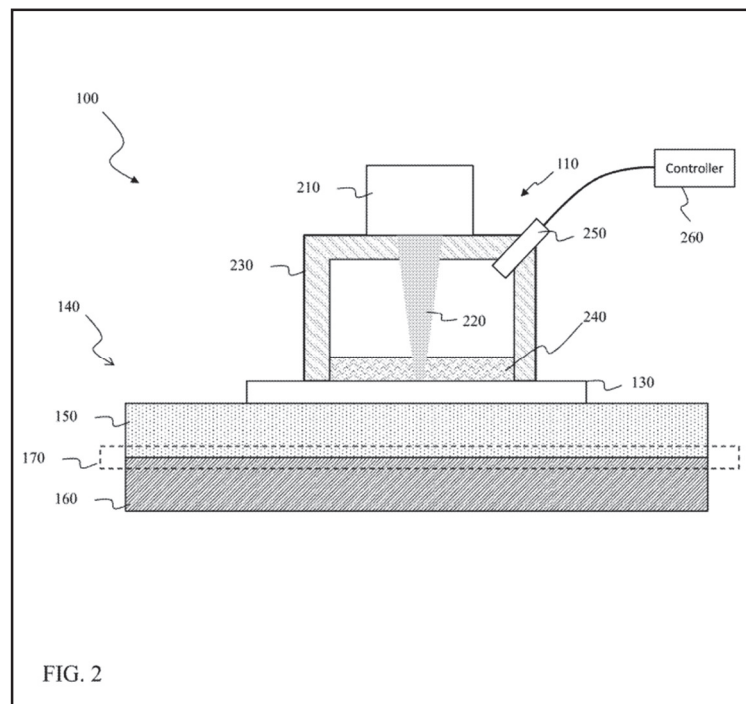
29. The specification of the Boeing ’670 Patent confirms my statements made earlier in this declaration that the stress analysis conducted at the Huntington Beach facility of Boeing is integrally connected in the way Boeing uses the invention disclosed in the ’684 Patent. On Col. 2, ll. 64-67 and Col. 3, ll. 1-6, the Boeing ’670

1 Patent describes the importance of such stress analyses, which I quote below (emphasis
2 added):

3 *“During operation, LBID 110 generates and directs laser*
4 *beam 120 toward test article 140. Laser beam 120 is*
5 *configured to deliver a calibrated amount of energy to the*
6 *inspection site. The calibrated amount of energy varies for*
7 *each test article. For test article 140, a **target amount of***
8 ***energy is computed that will produce a target amount of***
9 ***stress in test article 140 to test bond 170.”***

10 30. The purpose of the disclosures of the Boeing '670 Patent is to ensure that
11 the previously calculated amount of laser energy that leads to the desired calculated
12 stress at the joint 170 between the two bonded substrates 150 and 160 is delivered by
13 the laser of the LBID device. If the laser energy is too high then the stress generated
14 will be higher than the proof test level and that can cause unwanted failure within the
15 test article; and if it is too low then the generated stress will fall below the pre-
16 determined proof stress level and Boeing will be unable to tell if the inspected joint has
17 deteriorated in service.

31. The delivery of the calculated amount of laser energy is accomplished by applying a thermochromatic energy-absorbing material to the inspection site of a test article whose color change depends upon the level of laser energy absorbed by the material. The intensity of color change can be calibrated and related to the laser energy delivered to the test article, which ultimately controls the tensile stress delivered to the joint 170. As shown in Figure 2 of the Boeing '670 Patent (copied below), this intensity of color change is recorded and analyzed by installing a camera/analyzer system 250 in the vacuum chamber 230 of the LBID device 110. After analyzing the data, a controller 260 tunes the laser energy to the calculated value, if required.



32. I have provided an element-by-element analysis for Claim 13 of the '684 Patent below and discussed how each element is disclosed in the specification of the Boeing '670 Patent.

33. Again, Claim 13 of the '684 Patent recites:

A method for separating a coating from a substrate, the

1 *substrate having a first side and a second side transversely*
 2 *disposed in a first axis, the coating applied to the first side of*
 3 *the substrate such that the coating and substrate are axially*
 4 *spaced along the first axis in intimate facing contact to form*
 5 *a coating/substrate interface, the method comprising:*

6 *positioning a glass element along the first axis on the*
 7 *second side of the substrate;*

8 *directing a laser pulse in the first axis at the glass*
 9 *element;*

10 *propagating a stress wave through the glass element to*
 11 *the coating/substrate interface to generate a tensile force*
 12 *between the substrate and the coating; and*

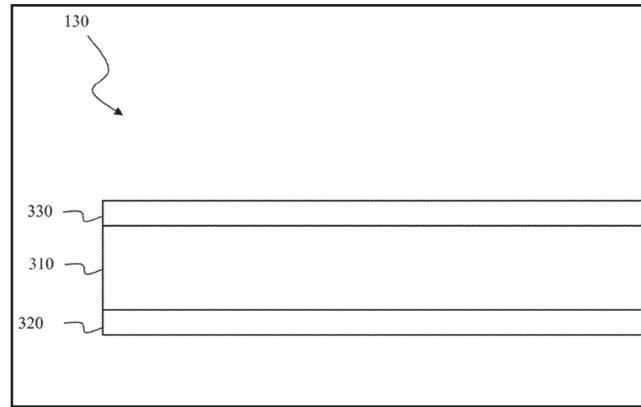
13 *separating the coating from the substrate as a result of*
 14 *the stress wave-generated tensile force.*

15 34. The claim element,

16 *“A method for separating a coating from a substrate, the*
 17 *substrate having a first side and a second side transversely*
 18 *disposed in a first axis, the coating applied to the first side of*
 19 *the substrate such that the coating and substrate are axially*
 20 *spaced along the first axis in intimate facing contact to form*
 21 *a coating/substrate interface, the method comprising,”*

22 appears to be met by the description of the Boeing '670 Patent, as it discloses a bond
 23 170 between two substrates 150 and 160, each having first and second sides, and are
 24 disposed along a first axis that is aligned with the laser beam 120 or 220 as illustrated
 25 in Figures 1 and 2 of the Boeing '670 Patent. The two substrates are in intimate facing
 26 contact with each other and form an adhesive interface or a bond 170. Substrate 160 is
 27 adhesively joined to the first side of the substrate 150.

35. The claim element, “*positioning a glass element along the first axis on the second side of the substrate*” appears to be met by the Boeing ’670 Patent as it discloses what it calls the “thermochromatic energy-absorbing” element 130. Figure 3 of the Boeing ’670 Patent, reproduced below, shows the geometrical structure of this element.



36. As described in the Boeing ’670 Patent, 310 is the laser absorbing overlay which is adhered to the underlying substrate by use of an adhesive layer 320. On the opposite surface of overlay 310, the thermochromatic energy-absorbing material 330 is applied. The Boeing ’670 Patent also discloses that the layer 310 can be made of a material that can function both as the laser absorbing material and for the thermochromatic function, in which case the layer 330 is not necessary. While the Boeing ’670 Patent does not disclose the specific material type that would be used to realize the invention, it is well-known that the color change in these thermochromatic materials upon heating results due to the change in their coordination number, the modification of their crystalline field or their chemical decomposition. Whether they are of organic or inorganic origin, they have a highly disordered structure that can be easily reversed from a crystalline phase to a disordered liquid crystal phase and vice-versa. These would modify the stress wave as covered by the ’684 Patent. It is clear from Figures 1 and 2 of the Boeing ’670 Patent that such glass elements are placed on

1 the second side of the substrate 150 that is opposite to the side where the second
2 substrate 160 is joined to form the test joint 170.

3 37. There are other locations in the disclosure of the Boeing '670 Patent
4 where the '684 Patent's glass element may be present, such as when Boeing uses glass
5 fiber composites as substrates or uses epoxies or adhesives to bond the two composite
6 substrates. Here, the adhesive 330 can also act as the '684 Patent's glass element.

7 38. The claim element "*directing a laser pulse in the first axis at the glass*
8 *element,*" is present and demonstrated in Figures 1 and 2 of the Boeing '670 Patent,
9 which show the laser beam as a line 120 (Fig. 1) or in the form of a cone 220 (Fig. 2).

10 39. The claim element, "*propagating a stress wave through the glass element*
11 *to the coating/substrate interface to generate a tensile force between the substrate and*
12 *the coating,*" is demonstrated in Figure 1 of the Boeing '670 Patent. The specification
13 provides details on how the initial compression stress wave 180 transmits through the
14 joint 170 and, upon reflection from the free surface of the second substrate 160 as a
15 tension wave 190, generates a tensile force at the test joint 170.

16 40. The claim element, "*separating the coating from the substrate as a result*
17 *of the stress wave-generated tensile force,*" appears to be met as soon as a weak bond
18 or a kissing bond is broken in Boeing's use of the invention of the Boeing '670 Patent,
19 as the strength of the deteriorated joint falls below the proof strength level that has
20 been predetermined by Boeing as the minimum strength needed at the joint for the safe
21 operation of its aircraft. It is noteworthy that, to set the laser energy corresponding to a
22 specified stress level, Boeing has to carry out strength measurements, each of which
23 results in the failure of the bond, and therefore appears to meet this claim element .

24 41. As the Court can appreciate from my discussion above, there are
25 significant LBI method-related activities being done at Boeing's Huntington Beach
26 facility in Southern California. This is fully consistent with my conversation with Mr.
27 Richard Bossi (who is credited with setting up the development of the LBI method
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1 inside the Boeing Company), who told me that he routinely travels to Boeing's
2 research facilities in Seal Beach and Huntington Beach to interact with the engineers
3 there for the development of the LBI method. Boeing uses the stress analyses it
4 conducts at the Boeing Huntington Beach facilities, which I had discussed in my
5 earlier declaration dated August 11, 2023, to determine the laser energy values and the
6 corresponding stress levels needed to implement the invention of the '684 Patent to
7 ensure the integrity of the critical joints and the safety of their aircraft. Mr. Bossi told
8 me that the wave mechanics simulation which was presented in his 2004 Society for
9 the Advancement of Material and Process Engineering (SAMPE) paper was conducted
10 by the engineers in the Huntington Beach facilities. He had also mentioned the on-
11 going laser ultrasound work at these facilities provided him insights that are needed for
12 developing the LBI method. Laser ultrasound is a non-destructive method that uses
13 low power laser pulses to generate the stress waves which upon reflection from an
14 interior flaw or delamination are analyzed for energy change upon their arrival back at
15 the test article's surface. The LBI method uses much higher laser energies, as it
16 requires breaking of a joint whose strength is still substantial but has fallen below a
17 prescribed proof strength level. Mr. Bossi and I discussed all this and how the laser
18 ultrasound experience of the engineers in Boeing's Southern California facilities was
19 helping him develop the LBI method.

20 42. Publications by the Boeing engineers from the Huntington Beach facility
21 show the material and other cross-sectional details of the stringer and frame (panel).
22 As described in the papers, all these elements are made using different types of
23 composites and joined together with different types of epoxies, including glass. Figure
24 4 shows that the frame or the stringer can actually have a fiberglass core. The glass
25 element changes the profile of the stress wave to enhance the tensile stress at the joint
26 to be tested. In this way, the invention of the '684 Patent covers Boeing's testing of
27 stringers by the LBI method. The invention of the '684 Patent includes the presence of
28

1 composite panels through which the laser-generated stress wave travels prior to
2 arriving at the joint to be tested. These composite panels can also act as the glass
3 element depending upon their location and composition. It is clear from the papers
4 published by the Boeing engineers that the Boeing facilities in Southern California
5 manufacture composite panels.

6 43. I understand that Mr. Bossi, who was the lead engineer for bond
7 inspection at Boeing, had outlined a similar plan for bond certification in Boeing
8 aircrafts as early as June of 2008 at the 4th FAA JAMS technology review meeting
9 held in Everett, WA. Slide 3 from his presentation, entitled, “*Aviation Industry*
10 *Perspective on the Presented Research*,” displays the wide body aircraft structures and
11 results from a stress analysis. As noted above, engineers at Boeing’s Huntington
12 Beach Facility have analyzed these wide body aircraft structures and have identified
13 areas where adhesion loss is expected and thus would require monitoring using the
14 invention of the ’684 Patent.

15 44. Boeing has advertised job openings in May 2023 through the present,
16 seeking structural stress analysts and test engineers in the Central District of California
17 for analyzing and validating (testing) the bonded adhesive joints.

18 45. Boeing appears committed to using the ’684 Patent’s invention for
19 manufacturing and inspecting of adhesive bonds in their entire fleet of aircraft,
20 including sections comprising of stringers and frames. They have even planned to
21 change the configuration of their entire airframe structural system so that the system
22 would be amenable to inspection by the laser bond inspection method that is based on
23 the ’684 Patent’s invention. This is evident from Figure 2 of Boeing’s recently
24 published patent application No. US 2023/0104854, where the upwardly and
25 downwardly pointing arrows 142 in Figure 2 are meant to indicate the travel path of
26 the interrogating laser-generated stress wave, which is disclosed in the invention of the
27 ’684 Patent.

1 46. I have appreciated the Court's detailed analysis and understanding of my
 2 first declaration in which I described the above stress analyses performed by Boeing's
 3 engineers in their Huntington Beach facilities. While rendering its Decision, the Court
 4 read my description of such stress analyses to mean that it was only a necessary
 5 precursor to the laser bond inspection activity and not something that would potentially
 6 infringe the '684 Patent's invention. I understand that such a conclusion was drawn by
 7 the Court because I did not make an explicit connection between these stress analyses
 8 and the '684 Patent's method claims. In this declaration, I have discussed how these
 9 analyses are in fact integrally connected to the '684 Patent's invention and may even
 10 infringe the '684 Patent's method claims by themselves. The stress analysis performed
 11 by Boeing engineers at Boeing's Huntington Beach facility is not only a necessary
 12 precursor to further laser bond inspection activity, but is something that, by itself, can
 13 infringe the invention of the '684 Patent. The mathematical work done by Boeing's
 14 engineers is not merely a precursor, but is required to practically perform the method
 15 claimed in the '684 Patent. For example, the laser pulse needs to be just enough to
 16 create the desired separation, so the mathematical work in calculating the needed pulse
 17 is an integral part of each step of the process and not a mere precursor. Such
 18 mathematical stress analysis work is only relevant to LBI, and cannot be used for other
 19 purposes.

20 47. For example, Claim 13, a method claim of the '684 Patent, reads as
 21 follows, with bold emphasis added:

22 *A method for separating a coating from a substrate, the*
 23 *substrate having a first side and a second side transversely*
 24 *disposed in a first axis, the coating applied to the first side of*
 25 *the substrate such that the coating and substrate are axially*
 26 *spaced along the first axis in intimate facing contact to form*
 27 *a coating/substrate interface, the method comprising:*

28 *positioning a glass element along the first axis on the*
 second side of the substrate;

1 *directing a laser pulse in the first axis at the glass*
 2 *element;*

3 *propagating and modifying a stress wave through the*
 4 *glass element to the coating/substrate interface to generate a*
 tensile force between the substrate and the coating; and

5 *separating the coating from the substrate as a result*
 6 *of the stress wave-generated tensile force.*

7 48. The method claims of the '684 Patent (that is, claims 13 to 24) include
 8 generating a stress wave near the surface of the test article by using an optical laser
 9 pulse. Among other things, the stress wave amplitude depends upon the energy of the
 10 laser pulse which can be controlled by tuning the laser source. Generally speaking, the
 11 higher the laser energy, the higher is the amplitude of the stress wave that is generated.

12 49. Next, this stress wave is modified by a glass element which can change its
 13 profile, if needed.

14 50. Next, this modified stress wave travels to the preselected "test joint"
 15 buried inside the test article. The more complex the part, the larger is the scattering
 16 and the larger are the losses in the wave energy by the time the stress wave reaches the
 17 "test joint," including after reflection from the rear surface of the test article or from
 18 the free surface of the glass element, such as described in the Boeing '433 Patent.

19 51. After undergoing the aforesaid energy or amplitude losses, the amplitude
 20 of the arriving tension wave must exceed the intrinsic strength of the interface for the
 21 joint to separate or fail, as in the '684 Patent, Claim 13. The choice of the laser pulse
 22 to be used to generate the initial stress wave, near the surface of the test article,
 23 depends upon these losses, and it should be so chosen such that the residual amplitude
 24 of the arriving stress wave at the test joint should exceed its strength on the day testing
 25 is performed. As discussed above, the energy losses depend upon wave scattering,
 26 which is specific to the geometry of the test article and further depends upon the type,
 27 arrangement, thickness, and geometries of different layers and materials used to make

1 the test article. The choice of the laser pulse, an element of the '684 Patent, Claim 13,
2 depends upon these losses. One must understand the source of these losses that are
3 intrinsic to the undamaged part that is being tested. This can be determined only by a
4 stress analysis of the type that is being done by the Boeing engineers at its Huntington
5 Beach facility. The stringer geometry is complex and, as such, has to be modeled by
6 using the finite element method which accurately models the glass fiber core,
7 composite plies, adhesives, and the complex non-planar geometry of each layer. This
8 then allows Boeing engineers to choose a laser pulse of enough energy to generates a
9 compressive stress wave of high enough amplitude near the surface of the test article
10 such that, after all the losses due to the wave scattering effects, the final tensile force at
11 the buried test joint is equal to the proof strength level, which has been predetermined
12 by Boeing's engineers as the safe acceptable level of the bond strength for the aircraft
13 to operate safely. The wave losses depend upon the location of the joint that is being
14 targeted, as the multi-materials and multi-geometries the interrogating wave
15 encounters affect the path and the distance it travels to reach the targeted joint.

16 52. In a complex part of the fuselage, such as where stringers are located,
17 Boeing must also determine the areas where such joints are located and are the most
18 vulnerable to failure. This is exactly what is done by the stress analyses that are
19 performed by Boeing's engineers at their Huntington Beach facility. The LBI
20 **procedure** (not just limited to the use of a particular LBI tool) is not done in a
21 vacuum. The stress analysis not only determines the critical locations within the test
22 article where failure can occur, but, the way Boeing applies the invention of the '684
23 Patent, it also requires information on the wave losses, as otherwise they cannot choose
24 the laser pulse of sufficient energy to ensure that the final stress at the targeted joint
25 equals the proof stress level, as **predetermined** by Boeing's safety engineers.

26 53. There is another very important reason why such stress analyses are part
27 of the way Boeing uses the invention of the '684 Patent. As I have discussed here,
28

1 Boeing uses the '684 Patent's invention for proof testing of critical joints. A laser
2 pulse of a given energy generates a stress wave with initial amplitude. After all the
3 aforesaid losses, let us assume that the final stress wave that arrives at the joint actually
4 causes its failure and physically forms a crack. Let us refer to this stress wave as a
5 "proof wave." Since the proof wave caused the failure, the strength of the targeted
6 joint had fallen below the proof strength level and therefore poses a serious risk to the
7 safety of the entire aircraft. Now how do Boeing's engineers know that such a failure
8 has been caused, as it is invisible to the eye and is deep-seated inside the aircraft
9 component? Boeing engineers use a low-amplitude stress wave or an "interrogation
10 wave," and launch it along the exact same path as the proof wave. The interrogation
11 wave is reflected by the delamination or the damage caused by the proof wave and
12 travels back towards the surface of the test article, where a detector analyzes the
13 energy and amplitude of the returning interrogation wave. Whether this energy loss in
14 the returning interrogation wave is due to the delamination caused by the proof wave
15 or it is simply due to the interaction with the multi-layer, multi-material geometrical
16 features of the undamaged part that were in the path of the interrogating wave must
17 now be resolved by Boeing's engineers. Indeed, this can be resolved only by the
18 sophisticated stress wave analyses of the type that Boeing performs at its Huntington
19 Beach facility, as such analyses are able to determine the losses from the wave
20 interacting with the features inherent in a completely healthy and undamaged part. If
21 the returning interrogation wave has features that do not match the calculated features
22 from such analyses, then the loss of energy and amplitude came from the damage
23 caused by the proof wave.

24 54. I called Mr. Bossi of Boeing via telephone on August 2, 2004, after
25 discovering his 2004 SAMPE paper in which several of my trade secrets that were
26 protected under a Proprietary Agreement with Boeing were disclosed. The Proprietary
27 Agreement was signed with Boeing's coating group (Doug Berry and Seana Kobak) in
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1 the year 2000 when Boeing samples were tested by using laser-generated stress waves
2 in my lab. I approached Mr. Bossi directly after receiving no response from either Mr.
3 Berry or Ms. Kobak after several phone calls and email messages.

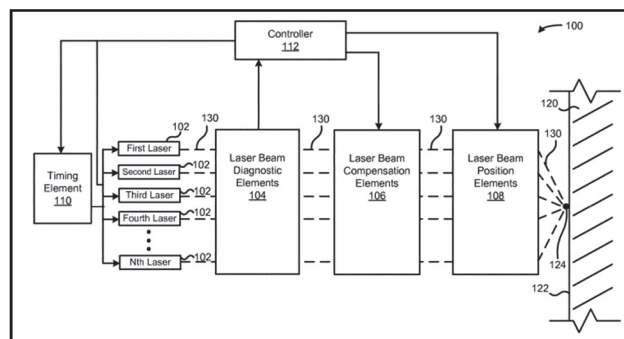
4 55. Mr. Bossi told me on his own that he was aware of my earlier '402 Patent.
5 The '684 Patent builds upon the '402 Patent in that it uses a glass element to enhance
6 the amplitude of the interrogating stress wave. Such an enhancement is necessary, as
7 the amplitude of the interrogating stress wave dissipates very quickly as the wave
8 travels through multiple fiber layers of the composite laminate.

9 56. I have also reviewed and analyzed United States Patent No. 10,239,155
10 ("the Boeing '155 Patent"), entitled, "Multiple Laser Beam Processing," with Alan
11 Stewart, Anthony Kay, Louis Zeldin, and Andrea Koumvakalis as the named
12 inventors. The Boeing '155 Patent is assigned to Boeing. I note that two of the
13 inventors, Anthony Kay and Andrea Koumvakalis, are listed as being from Southern
14 California, and therefore this patent likely represents work that was performed at
15 Boeing's Southern California facilities. The date of the underlying patent application
16 is listed as April 30, 2014. Andrea Koumvakalis has now retired. A web search
17 yielded details of a panel discussion where she was an invited panelist. The title of the
18 symposium was, "Emerging from a Pandemic - Women's Journeys in STEM." It was
19 held at the California State University Northridge, CA ("CSUN"), on September 22,
20 2021. A video recording of the panel discussion is publicly available at CSUN's
21 website (<https://library.csun.edu/events/wise-emerging/>) (last visited Oct. 31, 2023). A
22 profile of Dr. Koumvakalis, also published at the same website, states that she retired
23 in July 2021 and that, for the last 10 years prior to her retirement, she worked at
24 Boeing's El Segundo office. This therefore indicates that her work that became part of
25 the Boeing '155 Patent was performed in Southern California.

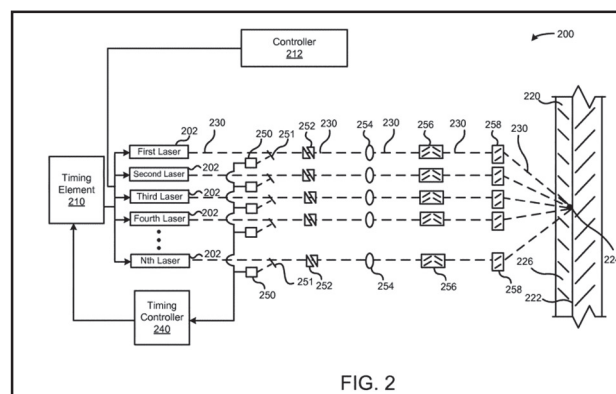
26 57. The Boeing '155 Patent describes a system that can deliver application-
27 specific laser pulses of desired temporal and spatial profiles, with prescribed energy
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intensities. A set of controllers can be tuned to essentially fire a laser pulse of the desired attribute, also referred to as the combined laser beam pulse 124 in the Boeing '155 Patent, onto a specific location of the workpiece for a particular application. The patent lists several potential applications for which the laser pulse 124 is being designed. Below, I cite directly from the Boeing '155 Patent (Col. 4, ll.56-68 to Col. 5, ll.1-3), also making reference to Fig. 1 of the patent, which I have also reproduced:

“The desired characteristics of the combined laser beam pulse 124 correspond with a desired processing of the workpiece 120. The desired processing can include modifying the workpiece 120 to form or inspect the workpiece. In some implementations, depending on the characteristics of the combined laser beam pulse 124, forming the workpiece 120 can include generating a shockwave that imparts localized compressive residual stresses in the workpiece, removes material from the workpiece, cuts the workpiece, etches the workpiece, marks the workpiece, or achieves other material formation processes. **Similarly, in certain implementations, depending on the characteristics of the combined laser beam pulse 124, inspecting the workpiece 120 can include generating a shockwave through the workpiece such as for a laser bond inspection process.**”



58. Figure 2 of the Boeing '155 Patent, reproduced below, shows a schematic that demonstrates how the initial compression stress wave is generated at the surface of the workpiece 220. It shows an overlay 226 through which the laser pulse 230 traverses such that its energy is confined to the surface 222 of the workpiece. The Boeing '155 Patent's specification further describes that the workpiece 120 and 220 can be a composite material that requires inspection using the LBI method. In Boeing's case, this workpiece will involve the composite epoxy joint. The composite substrate can be made using glass fibers, as it is widely known that Boeing uses glass fiber composites in various parts of its aircraft. The design of the laser pulse 230 is dependent upon the application at hand. More specifically with respect to the LBI process, the intensity, duration and spatial profile of the laser pulse 230 will depend upon the details of the part to be inspected, including its geometry, material, and most importantly, the depth at which the test joint is located. All these features will control the wave scattering losses that ultimately must be accounted for in the design of the initial laser pulse 230 that generates the compressive stress wave at the surface of the workpiece being inspected. Only after a range of such structures have been analyzed for losses, the controllers claimed in the Boeing '155 Patent can be designed. Thus, any work related to the Boeing '155 Patent is integrally connected to the '684 Patent's LBI invention.



1 59. One of the named inventors on the Boeing '155 Patent is Alan F. Stewart.
2 The patent lists his place of residence as Seattle, WA, where Boeing has admitted it
3 conducts the majority of its LBI testing. Like Richard Bossi, Alan Stewart is one of
4 the key engineers at Boeing who has led the development of the LBI method by
5 following the invention of the '684 Patent. He is listed as a named inventor on several
6 of Boeing's LBI-related patents, all of which, in some form or another, infringe claim
7 13 of the '684 Patent. Some of his patents and patent applications include: U.S. Patent
8 No. 9,804,127, with Richard Bossi and Marc Peehl, entitled, "Laser Testing of a Bond
9 Interface Between Two Dissimilar Materials"; U.S. Patent Pub. No. US 2013/0192372,
10 with Richard Bossi and Clarence Gordo, entitled, "Tension Wave Generation System";
11 U.S. Patent Pub. No. US 2016/0109343, with Richard Bossi and Marc Piehi, entitled,
12 "Bond Interface Testing"; U.S. Patent No. 9,625,423, with Richard Bossi and 8 other
13 inventors, entitled, "System and Method for Testing a Composite Structure Using a
14 Laser Ultrasound Testing System"; and U.S. Patent No. 9,250,213, with Richard Bossi,
15 Gary Georgeson, Clarence Gordon, Jeffrey Kollgaard and William Motzer, entitled,
16 "Ultrasound Inspection System for Inspecting a Test Object with Non-Planar
17 Features." There are a few others that relate to Boeing's LBI method, and he is listed
18 as the named inventor. The joint inventorship on the Boeing '155 Patent from
19 Boeing's two facilities located in Seattle and Southern California, along with its
20 content that appears to infringe the invention of the '684 Patent, is further proof that
21 Boeing's Seattle facilities induce and contribute to the engineers in their Southern
22 California facilities to infringe the claimed invention of the '684 Patent.
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1 I declare under penalty of perjury under the laws of the United States of
2 America that the foregoing facts are true and correct, based on my knowledge,
3 understanding, information, and belief.
4

5 Dated: 11/2/2023 _____
6

7 By: _____
8 Vijay Gupta
9