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Paper 39
Entered: February 20, 2020

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

GENERAL ELECTRIC COMPANY,
Petitioner,

v.

UNITED TECHNOLOGIES CORPORATION,
Patent Owner.

IPR2018-01442
Patent 9,695,751 B2

Before HYUN J. JUNG, SCOTT A. DANIELS, and
TERRENCE W. McMILLIN, *Administrative Patent Judges.*

DANIELS, *Administrative Patent Judge.*

JUDGMENT
Final Written Decision
Determining Some Challenged Claims Unpatentable
35 U.S.C. § 318(a)

I. INTRODUCTION

A. Background

General Electric Company ("GE" or "Petitioner") filed a Petition to institute an *inter partes* review of claims 1–4, 9, 10, 15, 16, and 23 of U.S. Patent No. 9,695,751 B2 ("the '751 patent"). Paper 1 ("Pet."). United Technologies Company ("UTC" or "Patent Owner") filed a Preliminary Response (Paper 7) to the Petition. We instituted trial on all challenged claims. Paper 8 ("Dec. on Inst."). UTC timely filed a Response. Paper 20 ("PO Resp."). Petitioner filed a Reply. Paper 28 ("Reply"). Patent Owner filed a Sur-Reply. Paper 37. We have jurisdiction under 35 U.S.C. § 6(b).

UTC indicates in its Response that it has disclaimed claims 1–2, 4, 9–10, 15, and 23, leaving only claims 3 and 16 and grounds 1 and 3 at issue in this proceeding. PO Resp. 1, n.1; Ex. 2014.

We issue this Final Written Decision pursuant to 35 U.S.C. § 318(a). Having reviewed the arguments of the parties and the supporting evidence, we find that GE has demonstrated by a preponderance of the evidence that each of the remaining challenged claims—i.e., claims 3 and 16 of the '751 patent—is unpatentable.

B. Additional Proceedings

GE states that the '751 patent is not asserted in any lawsuit. Pet. 1. Patent Owner states that there are no other proceedings relating to the '751 patent. Paper 5, 2.

C. The '751 Patent

The '751 patent (Ex. 1001), titled "Geared Turbofan Gas Turbine Engine Architecture," describes a gas turbine engine having fan blades driven by a fan turbine and a gear system, i.e., a "speed change system" disposed between the fan turbine and the fan blades. Ex. 1001, 1:55–67. Figure 2 of the ’751 patent is reproduced below.

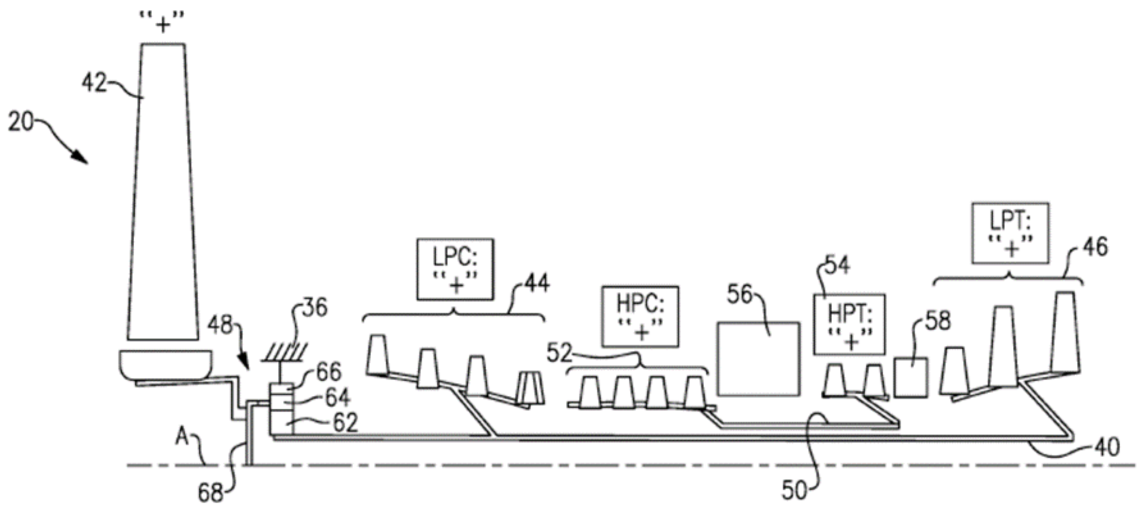

FIG.2

Figure 2 of the ’751 patent, above, depicts in schematic, a speed change system as an epicyclical planetary gearbox with input shaft 40 driving sun gear 62, which in turn drives intermediate gears 64, which intermesh with fixed ring gear 66 to drive fan 42 via carrier 68. *Id.* at 6:16–6:20. The claims recite a “fan drive turbine,” which as shown in Figure 2 above, is low pressure turbine (“LPT”) 46, which drives fan 42 via input shaft 40. *Id.* at 6:40–44. Also claimed is a “second turbine,” shown in Figure 2 as high pressure turbine (“HPT”) 54. *Id.* Fan 42 rotates when hot exhaust gases produced in combustor 56 are expanded through HPT 54 for producing engine thrust and through LPT 46 for driving fan 42. *Id.* at 5:5–9.

Figure 10 of the ’751 patent is reproduced below.

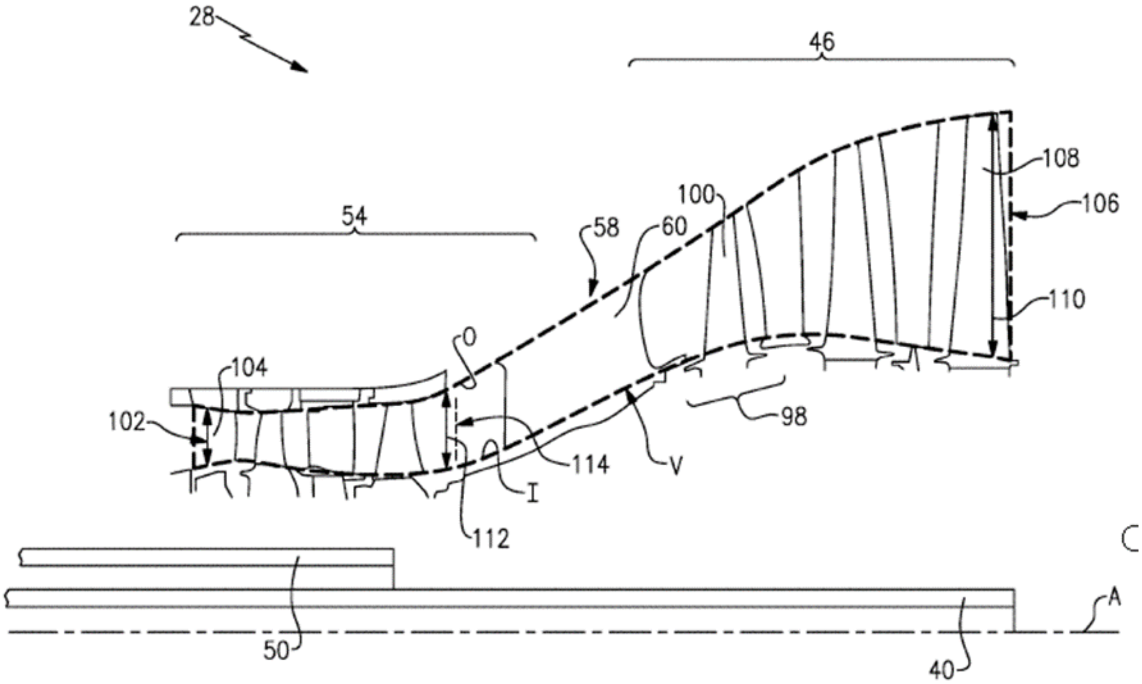

FIG.10

Figure 10 of the ’751 patent, above, illustrates a volume (generally expressed in terms of cubic inches) of turbine section 28 generally between inlet 102 of HPT 54, and exit 106 at the outlet of LPT 46. *Id.* at 10:25–29.

The ’751 patent describes that an important characteristic of the disclosed turbine section is “power density, which may be defined as thrust in pounds force (lbf) produced divided by the volume of the entire turbine section 28.” *Id.* at 10:23–25. Thrust, the ’751 patent explains, is understood to be “[t]he static thrust at the engine’s flat rated Sea Level Takeoff condition,” i.e., Sea Level Take Off thrust, or “SLTO thrust.” *Id.* at 10:29–40. Volume, the ’751 patent states, “extends from a most upstream end of the vane 104, typically its leading edge, and to the most downstream edge of the last rotating airfoil 108 in the low pressure turbine section 46. Typically this will be the trailing edge of the airfoil 108.” *Id.* at 10:49–53.

D. Illustrative Claims

Of the originally challenged claims, claims 1 and 15 are independent. Remaining challenged dependent claims 3 and 16 depend from independent claims 1 and 15, respectively. Claims 1, 2, and 3 illustrate the claimed subject matter and are reproduced below with certain limitations highlighted in italics:

> 1. A gas turbine engine comprising:
>
> a fan including a plurality of fan blades rotatable about an axis;
>
> a compressor section;
>
> a combustor in fluid communication with the compressor section;
>
> a turbine section in fluid communication with the combustor, the turbine section including a fan drive turbine and a second turbine, wherein the second turbine is disposed forward of the fan drive turbine and the fan drive turbine includes a plurality of turbine rotors with a ratio between a number of fan blades and a number of fan drive turbine rotors is between 2.5 and 8.5; and
>
> a speed change system configured to be driven by the fan drive turbine to rotate the fan about the axis; and
>
> *a power density* at Sea Level Takeoff greater than or equal to 1.5 lbf/in^3 and less than or equal to 5.5 lbf/in^3 and defined as thrust in lbf measured by *a volume of the turbine section in in^3 measured between an inlet of a first turbine vane in said second turbine to an exit of a last rotating airfoil stage in said fan drive turbine.*
>
> 2. The gas turbine engine as recited in claim 1, wherein the fan drive turbine has from three to six stages.
>
> 3. The gas turbine engine as recited in claim 2, wherein said number of fan blades is less than 18 and the second turbine has two stages.

Ex. 1001, 13:13–38 (emphases added).

E. The Alleged Grounds of Unpatentability

In view of UTC's disclaimer, the remaining claims 3 and 16, are challenged by GE as unpatentable on the following specific grounds.[1]

Reference(s)/Basis	35 U.S.C. §	Claims Challenged
Knip[2]	103	3 and 16
Knip and Decker[3]	103	3 and 16

F. The Level of Ordinary Skill in the Art

Factors pertinent to a determination of the level of ordinary skill in the art include: "(1) educational level of the inventor; (2) type of problems encountered in the art: (3) prior art solutions to those problems; (4) rapidity with which innovations are made; (5) sophistication of the technology, and (6) educational level of workers active in the field." *Envtl. Designs, Ltd. v. Union Oil Co*., 713 F.2d 693, 696–97 (Fed. Cir. 1983) (citing *Orthopedic Equip. Co. v. All Orthopedic Appliances, Inc.*, 707 F.2d 1376, 1381–82 (Fed. Cir. 1983)). Not all such factors may be present in every case, and one or more of these or other factors may predominate in a particular case. *Id.* Moreover, these factors are not exhaustive but are merely a guide to determining the level of ordinary skill in the art. *Daiichi Sankyo Co. Ltd, Inc. v. Apotex, Inc*., 501 F.3d 1254, 1256 (Fed. Cir. 2007).

[1] GE supports its challenge with the declaration of Dr. Magdy Attia, Ph.D (Ex. 1003), and UTC responds with a declaration from Dr. Zoltan Spakovszky, Ph.D, (Ex. 2001) and a declaration from Dr. James C. Williams, Ph.D, (Ex. 2043). *See infra*.

[2] Ex. 1006, Gerald Knip, *Analysis of an Advanced Technology Subsonic Turbofan Incorporating Revolutionary Materials*, NASA Tech. Memorandum 89868, (1987) ("Knip").

[3] Ex. 1007, U.S. Patent Appl'n. Publication No. 2006/0228206 A1 (Oct. 12, 2006) ("Decker").

In determining a level of ordinary skill, we also may look to the prior art, which may reflect an appropriate skill level. *Okajima v. Bourdeau*, 261 F.3d 1350, 1355 (Fed. Cir. 2001). Additionally, the Supreme Court informs us that "[a] person of ordinary skill is also a person of ordinary creativity, not an automaton." *KSR Int'l v. Teleflex Inc.*, 550 U.S. 398, 421 (2007).

We determined in our Institution Decision, concomitant with GE's proposal, that a person of ordinary skill in the art "would include someone who has a M.S. degree in Mechanical Engineering or Aerospace Engineering as well as at least 3–5 years of experience in the field of gas turbine engine design and analysis." Pet. 15 (citing Ex. 1003 ¶ 4); Dec. on Inst. 10.

UTC does not explicitly propose a different level of ordinary skill, nor openly dispute that Dr. Attia is a person of ordinary skill in the art under GE's proposal. PO Resp. 60. UTC argues, however, with respect to enablement of Knip, that Dr. Attia admits "he is 'not a materials expert or a metallurgist' and that determining which composites to use to implement Knip's advanced engine 'is not [his] area of expertise.'" *Id.* at 61.

To the extent UTC disputes GE's level of ordinary skill in the art and argues that Dr. Attia is not a materials expert or a metallurgist, we are not persuaded to alter our previously determined level of ordinary skill. As discussed in more detail in our enablement analysis *infra*, UTC presents no persuasive evidence or argument that a materials expert, such as Dr. Williams, is necessary with respect to determining enablement of Knip or to the comparison of the claims in the '751 patent with engine cycle analyses and other technical disclosures in the prior art. Dr. Williams may not need to be a person of ordinary skill in the art in order to testify as an expert under Rule 702, but rather must be "qualified in the pertinent art." *Sundance, Inc.*

v. DeMonte Fabricating Ltd., 550 F.3d 1356, 1363–64 (Fed. Cir. 2008). This is particularly true where the claims of the '751 patent do not recite any limitations pertaining to materials used in constructing a gas turbine engine.

On the complete record now before us, our review of the parties' arguments and evidence, as well as the asserted prior art, remains consistent with GE's asserted level of ordinary skill in the art. Accordingly, we accept GE's asserted level of ordinary skill in the art as it applies to the arguments and evidence in this proceeding.

II. CLAIM CONSTRUCTION

A. Legal Standard

In this *inter partes* review, claim terms in an unexpired patent are interpreted according to their broadest reasonable construction in light of the specification of the patent in which they appear. 37 C.F.R. § 42.100(b) (2018); *Cuozzo Speed Techs., LLC v. Lee*, 136 S. Ct. 2131, 2144–46 (2016) (upholding the use of the broadest reasonable interpretation standard).[4]

Claim terms are given their ordinary and customary meaning as would be understood by a person of ordinary skill in the art at the time of the invention and in the context of the entire patent disclosure. *In re Translogic Tech., Inc.*, 504 F.3d 1249, 1257 (Fed. Cir. 2007). If the specification "reveal[s] a special definition given to a claim term by the patentee that differs from the meaning it would otherwise possess[,] . . . the inventor's lexicography governs." *Phillips v. AWH Corp.*, 415 F.3d 1303, 1316 (Fed.

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[4] On October 11, 2018, the USPTO revised its rules to harmonize the Board's claim construction standard with that used in federal district court. Changes to the Claim Construction Standard for Interpreting Claims in Trial Proceedings Before the Patent Trial and Appeal Board, 83 Fed. Reg. 51,340 (Oct. 11, 2018) (amending 37 C.F.R. § 42.100(b) effective November 13, 2018). This rule change does not apply to this proceeding. *Id*.

Cir. 2005) (en banc) (citing *CCS Fitness, Inc. v. Brunswick Corp*., 288 F.3d 1359, 1366 (Fed. Cir. 2002)). We apply this standard to the claims of the ’751 patent.

B. Volume of the turbine section

We determined in our Institution Decision that “the volume of the turbine section ‘measured between an inlet of a first turbine vane in said second turbine to an exit of a last rotating airfoil stage’ includes a leading edge of a first turbine vane and trailing edge of a last rotating airfoil.” Dec. on Inst. 8 (citing Ex. 1001, 10:22–53, Fig. 10, 13:30–33).

Neither party disagrees with our initial construction. *See* Pet. 21 (GE explains that “that the volume of the turbine is measured to the last *rotating* airfoil”); PO Resp. 13 (UTC states that the Board’s “interpretation is consistent with the ’751 Patent’s embodiments.”). UTC expressly agrees with the Board’s construction. PO Resp. 14. Referring to the disclosure of the ’751 patent and Figure 10, UTC explains further that “the inlet 102 and exit 106 are at the ***leading edge of the vane 104*** and the ***trailing edge of the airfoil 108***, respectively. This reading aligns with the Board’s construction.” *Id.*

We do not alter our initial construction and, therefore, determine for purposes of this Decision that the volume of the turbine section “measured between an inlet of a first turbine vane in said second turbine to an exit of a last rotating airfoil stage” includes a leading edge of a first turbine vane and trailing edge of a last rotating airfoil. *See* Ex. 1001, 10:22–53, Fig. 10, 13:30–33.

C. Other Constructions

GE offers a construction for the claim term “frame structure.” Pet. 18–19. We need not provide explicit construction for this claim term because the term is not in dispute and a construction is not necessary for our determination of unpatentability. *See Vivid Techs., Inc. v. Am. Sci. & Eng'g, Inc*., 200 F.3d 795, 803 (Fed. Cir. 1999) (only those terms which are in controversy need to be construed, and only to the extent necessary to resolve the controversy)*., and see Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017) (applying *Vivid Techs.* in the context of an *inter partes* review).

III. ANALYSIS

We turn now to GE's asserted grounds of unpatentability and UTC's arguments and evidence to determine whether GE has met its burden with respect to claims 3 and 16 under 35 U.S.C. § 316(e).

A. The Legal Constructs of Obviousness

Section 103(a) forbids issuance of a patent when "the differences between the subject matter sought to be patented 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 person having ordinary skill in the art to which said subject matter pertains." *KSR*, 550 U.S. at 406.

The question of obviousness is resolved on the basis of underlying factual determinations, including: (1) the scope and content of the prior art; (2) any differences between the claimed subject matter and the prior art; (3) the level of ordinary skill in the art; and (4) when available, evidence such as commercial success, long-felt but unsolved needs, and failure of others. *Graham v. John Deere Co*., 383 U.S. 1, 17–18 (1966); *see KSR*, 550 U.S. at 407 ("While the sequence of these questions might be reordered in any particular case, the [*Graham*] factors continue to define the inquiry that controls."). The Court in *Graham* explained that these factual inquiries promote "uniformity and definiteness," for "[w]hat is obvious is not a question upon which there is likely to be uniformity of thought in every given factual context." *Graham*, 383 U.S. at 18.

The Supreme Court made clear that we apply "an expansive and flexible approach" to the question of obviousness. *KSR*, 550 U.S. at 415. Whether a patent claiming the combination of prior art elements would have been obvious is determined by whether the improvement is more than the predictable use of prior art elements according to their established functions. *Id*. at 417. To reach this conclusion, however, it is not enough to show merely that the prior art includes separate references covering each separate limitation in a challenged claim. *Unigene Labs., Inc. v. Apotex, Inc*., 655 F.3d 1352, 1360 (Fed. Cir. 2011). Rather, obviousness additionally requires that a person of ordinary skill at the time of the invention "would have selected and combined those prior art elements in the normal course of research and development to yield the claimed invention." *Id*.

In determining the differences between the prior art and the claims, the question under 35 U.S.C. § 103 is not whether the differences themselves would have been obvious, but whether the claimed invention as a whole would have been obvious. *Litton Indus. Prods., Inc. v. Solid State Sys. Corp*., 755 F.2d 158, 164 (Fed. Cir. 1985) ("It is elementary that the claimed invention must be considered as a whole in deciding the question of obviousness.").

Before us also is a single reference obviousness challenge, and besides the requirement of a reason to modify the reference, we must keep in mind that "[w]hat matters in the § 103 nonobviousness determination is whether a person of ordinary skill in the art, having all of the teachings of the references before him, is able to produce the structure defined by the claim." *Orthopedic Equip. Co., Inc. v. U.S.*, 702 F.2d 1005, 1013 (Fed. Cir.

1983). And, as a factfinder, we also must be aware "of the distortion caused by hindsight bias and must be cautious of arguments reliant upon *ex post* reasoning." *KSR*, 550 U.S. at 421. This does not deny us, however, "recourse to common sense" or to that which the prior art teaches. *Id*.

Against this general background, we consider the references, other evidence, and arguments on which the parties rely.

B. Claims 3 and 16—Alleged obviousness over Knip

Petitioner asserts that claims 3 and 16 would have been obvious over Knip. Pet. 28–53. Petitioner has established by a preponderance of the evidence that claims 3 and 16 would have been obvious for the reasons explained below.

1. Knip

Knip is a NASA technical memorandum titled "Analysis of an Advanced Technology Subsonic Turbofan Incorporating Revolutionary Materials." Ex. 1006, 1.[5] Knip discloses an advanced two-spool geared turbofan engine using advanced and futuristic composite materials to evaluate "improvements in engine performance and thrust-to-weight ratio relative to current metallic materials." *Id.* at 2.[6] Using "aggressive component efficiencies based on these new materials," Knip specifically describes a "two-spool, advanced engine [having] an overall pressure ratio of 87, a bypass ratio of 18, a geared fan, and a turbine rotor-inlet temperature

[5] Unless otherwise noted, we use GE's exhibit numbers, e.g., Ex. 1006, 1–25, for references to Knip, as well as for GE's other cited prior art references and evidence.
[6] A "two spool" engine is generally understood to have two separate shafts for the HPT and the LPT, thus permitting the shafts, i.e., "spools," to essentially match the local airflow inside the engine and rotate at different speeds.

of 3085 ºR." *Id.* Relative to a baseline engine based on current technology in 1987, Knip discloses that the advanced engine provides a 36 percent reduction in engine weight and a 33 percent improvement in fuel efficiency. *Id.*

Knip discloses modification of various parameters and configurations of the advanced engine, and performing an engine cycle analysis "to define an engine cycle based on thrust specific fuel consumption (TSFC)." *Id.* at 4. Further, Knip acknowledges that "to optimize the engine in terms of TSFC and weight, the engine flowpath must be considered to identify possible tradeoffs required of the cycle to achieve an acceptable gas path geometry." *Id.* at 6. In comparing the advanced engine to the baseline engine, Knip explains that certain parameters were modified based on the flowpath studies, such as reducing the stages in the HPT from three to two, and notes, for example, that "[t]hese changes reduced the length of the transition duct between the HPT and the LPT in addition to reducing engine weight. The resulting flowpath for the advanced turbofan engine is shown in figure 13." *Id.* at 8. Figure 13 from Knip, illustrating the "Advanced Engine Flowpath" is reproduced below.

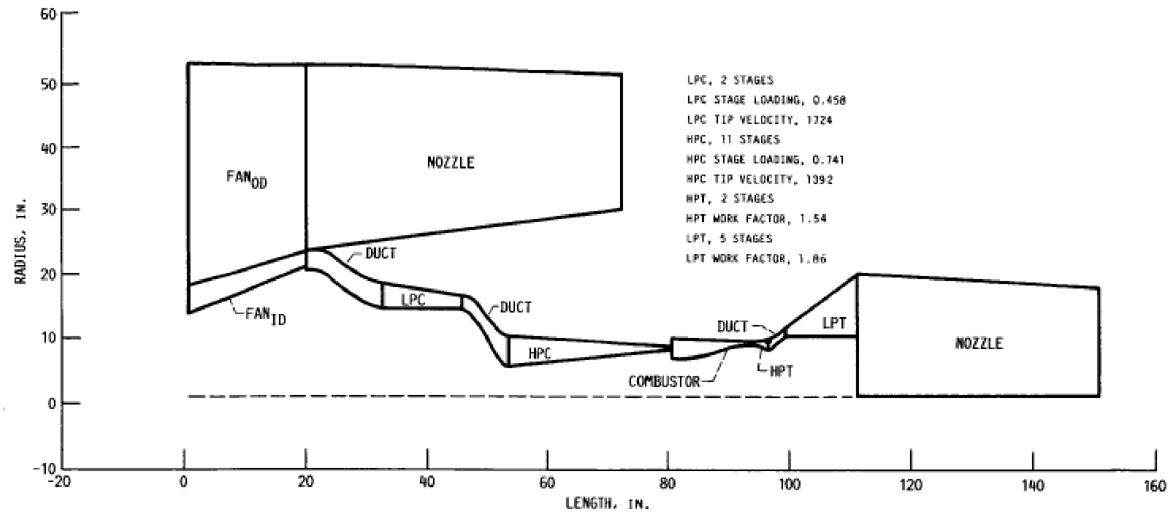


FIGURE 13. - ADVANCED ENGINE FLOWPATH; TOTAL ENGINE WEIGHT, 4866 LB.

Figure 13 of Knip, above, discloses a turbine section including a two-stage HPT and a five-stage LPT connected by a duct, following a combustor and compressor section extending from the fan. In comparison, the "Baseline Engine Flowpath" is shown below in Knip's Figure 14.

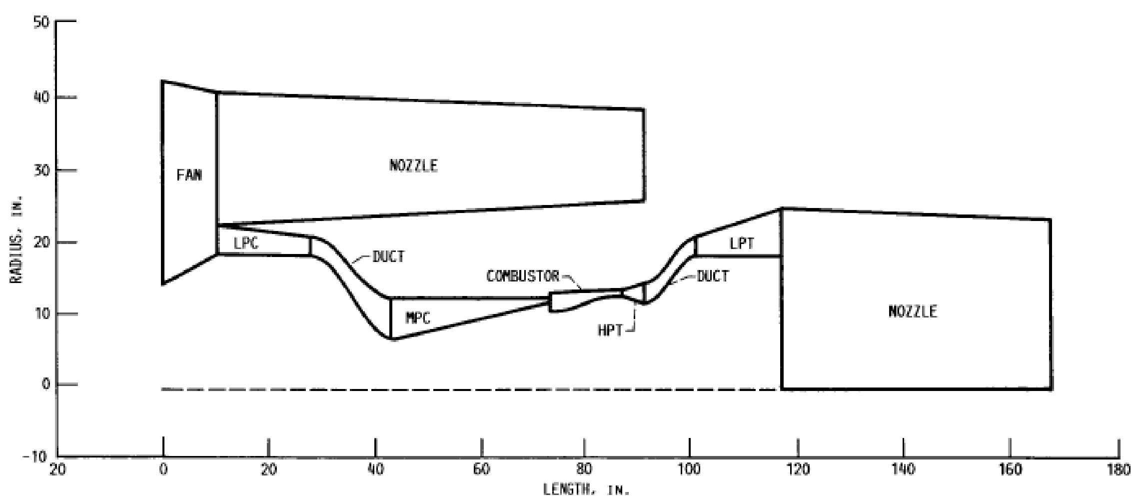


FIGURE 14. - BASELINE ENGINE FLOWPATH; TOTAL ENGINE WEIGHT, 6980 LB.

The baseline engine flowpath is illustrated in Knip's Figure 14, above, also having a two-stage HPT and a five-stage LPT. *Id.* at 11. Figures 13 and 14 depict the respective turbofan engine flow paths on an x-y axis providing relative engine component radii measurements (inches) along the vertical axis, and component length (inches) along the horizontal axis. Comparing Figures 13 and 14, Knip explains that the advanced engine flowpath is shorter, having an overall length of 152 inches, yet has a larger diameter of 106 inches, compared to the baseline engine flowpath. *Id.* at 21.

Because enablement could be dispositive of any analysis based on Knip in this proceeding, we initially address this issue raised by UTC.

2. Whether Knip is sufficiently enabled

UTC argues that Knip is not enabled. PO Resp. 44–65. Specifically, UTC argues that Knip describes a futuristic design using revolutionary composite materials and "never intended to equip anyone to create its 'advanced engine.'" *Id.* at 44 (citing Ex. 2015 ¶65). GE counters that Knip is sufficiently enabling for a person of ordinary skill in the art "to make and use the invention disclosed by the 751 Patent, as suggested by Knip." Reply 25 (citing *In re Antor Media Corp.*, 689 F.3d 1282, 1290 (Fed. Cir. 2012)).

Knip "is presumptively enabling barring any showing to the contrary by a . . . patentee." *In re Antor*, 689 F.3d at 1288. To rebut this presumption, UTC "must generally do more than state an unsupported belief that a reference is not enabling." *In re Morsa*, 713 F.3d 104, 110 (Fed. Cir. 2013). "To be enabling, the specification of a patent must teach those skilled in the art how to make and use the full scope of the claimed invention without 'undue experimentation.'" *Genentech, Inc. v. Novo Nordisk, A/S*, 108 F.3d 1361, 1365 (Fed. Cir. 1997) (*quoting In re Wright*, 999 F.2d 1557, 1561 (Fed. Cir. 1993)). "[A] patent specification complies with the statute even if a 'reasonable' amount of routine experimentation is required in order to practice a claimed invention." *Enzo Biochem, Inc. v. Calgene, Inc.*, 188 F.3d 1362, 1371 (Fed. Cir. 1999). Also, whether or not Knip's advanced engine was ever successfully implemented is not the proper consideration in our analysis here. *See Beckman Instruments, Inc. v. LKB Produkter AB*, 892 F.2d 1547, 1551 (Fed. Cir. 1989) ("Even if a reference discloses an inoperative device, it is prior art for all that it teaches.").

Factors relevant to a determination of undue experimentation include: (1) the quantity of experimentation necessary, (2) the amount of direction or guidance presented, (3) the presence or absence of working examples, (4) the nature of the invention, (5) the state of the prior art, (6) the relative skill of those in the art, (7) the predictability or unpredictability of the art, and (8) the breadth of the claims. *In re Wands*, 858 F.2d 731, 737 (Fed. Cir. 1988).

a. The first and sixth Wands factors

We address the first and sixth *Wands* factors together because UTC argues that it would take "extraordinary experimentation" for a person of ordinary skill in the art to implement Knip's advanced engine. PO Resp. 60 (citing *Wyeth & Cordis Corp. v. Abbott Labs*., 720 F.3d 1380, 1384 (Fed. Cir. 2013)). Extraordinary experimentation would have been necessary, UTC argues, because a person of ordinary skill in the art such as Dr. Attia was not a materials expert and "would have been in no position to select, develop, and implement the 'revolutionary' materials necessary for Knip's advanced engine without undue experimentation." *Id.* at 61 (citing Ex. 2043 ¶¶ 17–26; Ex. 2015 ¶¶ 57–64). UTC argues that Dr. Attia would have to perform undue experimentation to implement Knip's engine because "Knip requires ceramic composites so stable and effective as to be suitable for use with an ***uncooled*** turbine rotor inlet (T_{41} temperature) of 3,085 °R." *Id.* at 61–62 (citing Ex. 1006, 2, 4, 7).

UTC presents the declaration of Dr. James C. Williams, a professor of Materials Science and Engineering and Honda Chair Emeritus at The Ohio

State University and a Distinguished Research Professor at the University of North Texas. Ex. 2043 ¶ 3. Dr. Williams echoes UTC's contentions that at the time of the filing of the '751 patent implementing engines using uncooled ceramic matrix composites (CMC's) remained still a long way off. *See id.* ¶ 22 ("[M]ore than four years after the Critical Date, researchers working with NASA were still assuming that CMCs would need to be cooled in order to be used in the turbine of a large engine with a high turbine inlet temperature (e.g. Knip's advanced engine).").

We appreciate that Knip describes a purpose of its advanced engine design "was to . . . determine the approximate cycle and configuration for a turbofan engine incorporating revolutionary all-composite materials," such as CMCs. Ex. 1006, 2. However, the revolutionary materials and relevant efficiency characteristics are considered and analyzed in Knip, not recited in the claimed invention. Whether or not Knip's advanced engine was ever successfully implemented due to these materials is not the proper consideration in our analysis here.

The appropriate question is whether Knip is enabled relative *to the claimed invention*. *See In re Antor*, 689 F.3d at 1290 (The Federal Circuit explained that "a prior art reference need not enable its full disclosure; it only needs to enable the portions of its disclosure alleged to anticipate the claimed invention."). Here, the claims contain no materials-type limitations. Thus, the correct inquiry is whether one of ordinary skill in the art, who need not be a materials expert, is provided with sufficient parameters in Knip to determine, without undue experimentation, a "power density at Sea Level Takeoff" of the advanced engine within the range of 1.5 to 5.5 lbf/in^3, based on the ratio of SLTO thrust and volume of the turbine section, as recited in claim 1. *See Elan Pharm., Inc. v. Mayo Found. for Med. Educ. & Research*, 346 F.3d 1051, 1055 (Fed. Cir. 2003) ("The determination of what level of experimentation is 'undue,' so as to render a disclosure non-enabling, is made from the viewpoint of persons experienced in the field of the invention.").

All of UTC's arguments with respect to quantity of experimentation are based on the erroneous assertion that Knip's advanced engine, including the use of futuristic uncooled composite blade materials, must be taught by Knip to achieve the actual implementation of the advanced engine itself. *See, e.g.*, PO Resp. 63 (UTC argues that "many years of development remain in order to implement CMCs into ***uncooled rotating*** turbine blades operating at 3,085 °R as specified by Knip."); *see also Elan Pharm.*, 346 F.3d at 1055 ("It is not, however, necessary that an invention disclosed in a publication shall have actually been made in order to satisfy the enablement requirement.").

UTC argues further that Knip provides no guidance or teaching of "what specific materials to use or how to achieve the 'successful implementation' required by Knip's advanced engine." PO Resp. 50 (citing Ex. 1006, 2). UTC asserts that Knip provides even less guidance as to how to implement its advanced engine using these advanced materials than the Federal Circuit found in *Impax Laboratories, Inc. v. Aventis Pharmaceuticals Inc.*, 468 F.3d 1366 (Fed. Cir. 2006). *Id.* at 51. In *Impax*, the court found that there was no specific identification of the compound, riluzole, in the prior art reference as a treatment for ALS, and "therefore, [the reference] cannot enable treatment of ALS with riluzole." *Impax*, 468 F.3d at 1383. The facts in *Impax* are different from those before us. The invention recited in claim 1 of the '751 patent *does not* recite any type of special materials for making a gas turbine engine. The claimed invention focuses on a ratio of known engine parameters—SLTO thrust and turbine volume. Ex. 1001, 13:28–33. In fact, it is not clear that there is an "invention" in claim 1 since claim 1 has been disclaimed. *See* Ex. 2014 (disclaiming all but claims 3 and 16 in the '751 patent). Regardless, UTC's argument based on Knip's consideration of futuristic material capabilities is not persuasive because the argument incorrectly contends that Knip's advanced engine implementing the use of specific futuristic uncooled composite blade materials must be physically achievable based on the reference's disclosure itself. We therefore turn our attention, below, to the proper consideration of whether Knip is enabling relative to the elements of the claimed invention.

With respect to the "power density" limitation and its defining ratio of SLTO thrust and turbine section volume in claim 1, the quantity of experimentation is best explained by Dr. Attia. Dr. Attia testifies that a person of ordinary skill in the art would have known how to determine Knip's turbine section volume by hand, and alternatively that "[c]omputer assisted modeling would have been the preferred method of a [person of ordinary skill in the art (POSITA)] due to its improved accuracy and reduced calculation time, as compared to a manual calculation." Ex. 1003 ¶ 106. With respect to SLTO thrust, Dr. Attia explains that "Knip discloses many, but not all, of the relevant variables for calculating the SLTO thrust." *Id.* ¶ 102. Dr. Attia explains further that "a POSITA would have been able to make intelligent estimates for the remaining variables in order to produce an accurate range of SLTO thrust values." *Id.* Given Knip's advanced engine design parameters, Dr. Attia testifies persuasively that Knip's SLTO thrust is calculable from these "values and parameters . . . input into GasTurb 9, a well-known cycle analysis and design software that is quite inexpensive and available to the public." *Id.* ¶ 103 (citing Ex. 1035).

From Dr. Attia's testimony, we understand that there is some necessity of experimentation and estimation, particularly in determining the SLTO thrust. Ex. 1003 ¶ 102. Dr. Attia's testimony that such estimation and assumptions are within the level of ordinary skill in the art is essentially unrebutted. Although Dr. Spakovszky explains how his engine modeling analysis differs from Dr. Attia's and that it relies on different estimates, Dr. Spakovszky is able to calculate off-design SLTO thrust from Knip's disclosure. *See* Ex. 2015 ¶ 20 (Dr. Spakovszky testifies that "the above-described process can be followed to estimate Knip's SLTO thrust as accurately as possible, given the limited information provided in Knip."). We find that the testimony of both declarants tends to show fairly routine, as opposed to undue, experimentation. Accordingly, we find these *Wands* factors weigh in favor of GE.

b. The second Wands factor

Knip provides certain engine design parameters and analysis for its advanced engine, but there is essentially no guidance in Knip itself relevant to the efficiency concept or determination of SLTO thrust or "power density." In this case, GE has relied on the level of ordinary skill in the art, as explained by Dr. Attia and the Dev reference, to bridge the gap between Knip's advanced engine and the determination of SLTO thrust and "power density." Pet. 31 (citing Ex. 1003 ¶¶ 98–111.) Thus, we find very little, if any, guidance in Knip as to the determination of the "power density" limitation in claim 1. We do not find compelling UTC's continued assertion that Knip fails to explain *how* to successfully implement an advanced engine with futuristic composite components. *See* PO Resp. 50 ("Knip could not provide guidance as to how to implement 'revolutionary composite materials' in an aircraft engine without first knowing what specific materials would be available to future engine designers."). Regardless, because there is little to no guidance in Knip as to "power density," we find this factor weighs in UTC's favor.

c. The third and fourth Wands factors

The third and fourth *Wands* factors, considering the presence or absence of working examples and the nature of the invention, essentially stand together on the facts of this case. We disagree with UTC's position that the nature of the invention in claim 1 can be broadly surmised as "improving the performance of a geared turbofan engine." PO Resp. 55 (citing Ex. 1001, 1, 19). This may be a desired result or goal, but it is too ambiguous a statement to reflect the actual invention described in the specification and recited in the claims. Because the basic components of a fan, a compressor, a combustor, and a turbine section are well known to those of ordinary skill in the art, the nature of the invention in claim 1 must include the "power density" limitation and the recited range between 1.5 and 5.5 lbf/in^3.

UTC argues that there is no working example of an advanced engine in Knip because "[c]ritically, the 'revolutionary' all-composite turbine blades assumed by Knip for its 'advanced engine' were not available at the time of Knip's publication in 1987, nor by the time of the '751 Patent in 2012." PO Resp. 52. As discussed above, enablement does not require that Knip's advanced engine was actually implemented. *See Beckman*, 892 F.2d at 1551. UTC's argument with respect to composite blade materials is not persuasive because it does not identify or address sufficiently the nature of the invention in claim 1, which includes "power density," a limitation which does not require any special materials characteristics or composite turbine blades.

It is true that Knip does not expressly analyze or provide an express example of determining a "power density" engine characteristic as recited in claim 1. *See generally* Ex. 1006, 2–9. Yet GE has explained, supported by testimony from Dr. Attia, that a person of ordinary skill in the art would have been able to determine the volume of Knip's turbine section and reasonably estimate a SLTO thrust to attain "a power density between 4.13 and 4.95, which is within the claimed range of 1.5 lbf/in^3 to 5.5 lbf/in^3." Pet. 35 (citing Ex. 1003 ¶¶ 106–111). Weighing Knip's lack of an express example against GE's arguments as to what a person of ordinary skill would have understood and been able to determine from Knip's disclosure, we find these factors to be neutral in our *Wands* analysis.

d. The fifth Wands factor

The fifth *Wands* factor, the state of the prior art, weighs in favor of finding Knip's disclosure enabled relative to the claimed invention. This factor considers whether the prior art demonstrates that the knowledge of a person of ordinary skill in the art would have been able to fill in any gaps in Knip's disclosure. We find that it would have. From Dev's Figure 22, reproduced below, we understand that engine thrust, including SLTO thrust, as well as the volume of the engine as a whole, including the turbine section, are known and related variables in the art relating to engine efficiency regardless of whether one refers to the ratio as "power density."

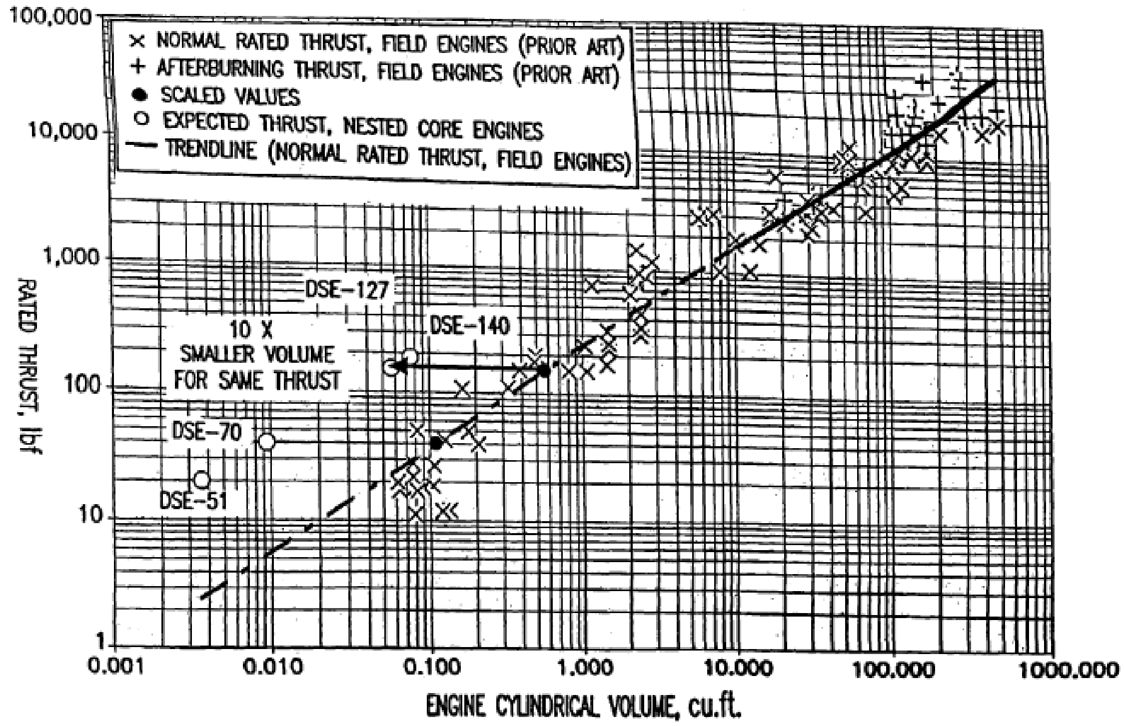


FIG.22

Dev's Figure 22, above, depicts rated thrust (lbf) compared with engine cylindrical volume (cu.ft.), illustrating that, compared to conventional gas turbine engines, nested core engines generate the same thrust at a smaller volume. Ex. 1032, 33. This strongly suggests that a person of ordinary skill in the art would have understood the relationship of SLTO thrust and engine volume as a measure of engine efficiency that would be valuable for evaluating engine performance. *See* Ex. 1003 ¶ 74 (Dr. Attia testifies that "Dev's improved engines (represented by the white circles) were expected to produce the same thrust with a much smaller engine volume (see red annotations). This was known in the art to be beneficial because of the resulting reductions in engine weight and improvements in fuel efficiency.").

e. The seventh Wands factor

The seventh *Wands* factor is the predictability of the art. Discussing how the concept of "power density" was known in the art, Dr. Attia explains that "[f]igure 22 [in Dev] discloses the expected relationship of thrust to engine volume (i.e., power density) for prior art engines ('X' and '+')." Ex. 1003 ¶ 74. Moreover, given that the relationship of engine volume to thrust was a known consideration in engine efficiency, Knip discloses a mechanical invention, which is "an art where the results are predictable." *Spectra-Physics, Inc. v. Coherent, Inc.*, 827 F.2d 1524, 1533 (Fed. Cir. 1987). Accordingly, this factor weighs in favor of concluding that Knip's advanced engine analysis is enabled.

f. The eighth Wands factor

Finally, the eighth *Wands* factor is the breadth of the claims. As the base claim, claim 1 is the broadest claim and, after reciting general components of a gas turbine engine, is limited to "a ratio between a number of fan blades and a number of fan drive turbine rotors . . . between 2.5 and 8.5," and "a power density at Sea Level Takeoff greater than or equal to 1.5 lbf/in^3 and less than or equal to 5.5 lbf/in^3." Ex. 1001, 13:24–29. Further, "power density" is defined in claim 1 as "as thrust in lbf measured by a volume of the turbine section in in^3 measured between an inlet of a first turbine vane in said second turbine to an exit of a last rotating airfoil stage in said fan drive turbine." *Id.* at 13:30–33.

Knip discloses a fan blade to drive rotor ratio of 4.6, within the range of claimed values. Pet. 30 (citing Ex. 1003 ¶ 96). And, although the term "power density" does not appear in any of the cited references, this term is defined in claim 1 as relating thrust to engine volume (or partial engine volume, e.g., turbine section) and is a concept known by those of ordinary skill in the art as a defining gas turbine engine efficiency characteristic. *See* Ex. 1032, Fig. 22; *see also* Ex. 1003 ¶ 75. Balancing the known concept and analysis in Dev of thrust to engine, or turbine section, volume against the fact that the prior art does not expressly disclose the recited power density range 1.5 to 5.5 lbf/in^3, we find that the breadth of claim 1 is neutral as to undue experimentation.

g. Conclusion as to the Wands factors

A person of ordinary skill in the art at the time of the invention presented with Knip's disclosure, regardless of the advanced nature of the materials discussed, would have understood that Knip disclosed a specifically sized engine as denoted by the drawing scale including axes measuring in inches the radius and length of the exemplary engines and that from such detailed drawings the volume of the turbine section could be determined. *See* Ex. 1003 ¶ 107 ("DataThief is a 'program to extract (reverse engineer) data points from a graph' . . . .") (citing Ex. 1037). Although Knip does not disclose a specific SLTO thrust for the advanced engine, we are persuaded that a person of ordinary skill in the art would have understood "SLTO thrust is the amount of thrust required to take off at sea level, and . . . it is possible to calculate an engine's SLTO thrust based on the engine's design." Ex. 1003 ¶ 99. From Figure 22 in Dev, we find that a person of ordinary skill in the art also would have further understood the known relationship between engine volume, including turbine volume, and SLTO thrust and how to make reasonable estimates and assumptions from the given engine design information in Knip and in accordance with the testimony of Dr. Attia and Dr. Spakovszky. Ex. 1032, 33. And, as discussed in further detail below, we are persuaded that a person of ordinary skill in the art would have been motivated to use such estimates along with the known engine parameters to determine an efficiency value for what claim 1 refers to as "power density," as it is a helpful engine design and efficiency parameter. *Id.* Taken in totality, the *Wands* factors support the conclusion that Knip is an enabling reference.

3. Analysis – Claims 1, 2, and 3

Because claim 3 depends from claim 2, which in turn depends from claim 1, we address the respective claims in order. Our analysis begins by assessing the similarities and differences between the prior art and claim 1.

a. Claim 1

Claim 1 is drawn to, *inter alia*, "[a] gas turbine engine," and requires, *inter alia*, "a fan including a plurality of fan blades," "a compressor section," "a combustor," "a turbine section," and "a speed change system." Ex. 1001, 13:12–26. These elements, GE argues, and as explained by Dr. Attia and discussed in the Background section of the '751 patent, are generally known to those of ordinary skill in the art to be components of a gas turbine engine. *Id.* at 1:19–41; Ex. 1003 ¶¶ 18–21, 32–35.

GE argues that Knip discloses a gas turbine engine including a geared fan having a plurality of blades and a compressor section in fluid communication with a combustor section. Pet. 26 (citing Ex. 1006, 3, Fig. 13; Ex. 1003 ¶¶ 19, 91–94). GE argues further that Knip discloses a turbine section having an LPT, i.e., a fan drive turbine, and a HPT, i.e., a second turbine "disposed forward of the fan drive turbine," as called for in claim 1. *Id.* at 28–29 (citing Ex. 1006, Fig. 13). GE argues that Knip also discloses a geared, speed change system—that is, a gearbox, permitting the fan to rotate at a different speed than the LPT. *Id.* at 30 (citing Ex. 1003 ¶ 97).

Claim 1 also recites that "the fan drive turbine includes a plurality of turbine rotors with a ratio between a number of fan blades and a number of fan drive turbine rotors is between 2.5 and 8.5." According to GE, the claimed ratio between the number of fan blades and the number of fan drive turbine rotors is taught by Knip disclosing 23 fan blades and a five-stage fan drive turbine, leading to a ratio of 4.6, which is between 2.5 and 8.5 as recited in claim 1. Pet. 30 (citing Ex. 1006, 11, Table II). UTC does not dispute that these claim elements are either known components of gas turbine engines or disclosed by Knip. *See generally* PO Resp. 15–68.

UTC focuses their arguments on certain structural and functional limitations of claim 1, namely

> *a power density* at Sea Level Takeoff greater than or equal to 1.5 lbf/in^3 and less than or equal to 5.5 lbf/in^3 and defined as thrust in lbf measured by *a volume of the turbine section in* in^3 *measured between an inlet of a first turbine vane in said second turbine to an exit of a last rotating airfoil stage in said fan drive turbine.*

Ex. 1001, 13:28–33 (emphases added). UTC argues that Knip does not teach or disclose the claimed "power density" and its defining characteristics, specifically the ratio of SLTO thrust to turbine section volume and the range of 1.5 to 5.5 lbf/in^3 as set forth in claim 1. PO Resp. 15–16. UTC argues that "only with the publication of the '751 Patent did the industry learn for the first time of 'power density,' its utility as an engine design parameter, the effective range of the 'power density' parameter, and how to achieve that range." *Id.* at 7. UTC contends that GE and Dr. Attia's analysis of Knip's power cycle and engine flowpath is hindsight and that a person of ordinary skill in the art "would have had no reason to derive SLTO thrust or turbine section volume values, relate them to one another in a ratio, and manipulate the values of such a ratio to arrive in the claimed range—unless they had first seen and studied the '751 Patent." *Id.*

In addition, UTC asserts that in Knip's Figure 13 "[t]here is neither 'a first turbine vane in said second turbine,' nor 'a last rotating airfoil stage in said fan drive turbine.'" *Id.* at 15. More specifically, UTC argues that the Petition, itself, fails to identify in Knip "a first turbine vane" in the HPT because "Knip's Figure 13 lacks sufficient detail to yield a 'power density' value consistent with the board's construction of turbine section volume." *Id.* at 15–25. Also, UTC argues that the proper engine modeling analysis performed by UTC's declarant, Dr. Spakovszky, shows that "the power density of Knip's advanced engine is outside the claimed range" of 1.5–5.5 lbf/in^3. *Id.* at 25–44. We address these arguments below.

Because they are related, we address initially two arguments raised by UTC, that is, (*a*) whether Knip discloses sufficiently to one of ordinary skill in the art "a first turbine vane in said second turbine" and "a last rotating airfoil stage in said fan drive turbine" as called for in claim 1, and (*b*) whether the Petition sufficiently identified in Knip the element of "a first turbine vane" in accordance with 37 C.F.R. § 42.104(b)(4)–(5). Pet. 15–23 (citing Ex. 1001, 13:31–33).

b. Whether Knip discloses sufficiently to one of ordinary skill in the art "a first turbine vane in said second turbine" and "a last rotating airfoil stage in said fan drive turbine"

The scope and content of Knip is a main point of contention in this proceeding. *See* PO Resp. 9 (UTC argues that Knip is limited "to evaluating the 'possib[le]' benefits of revolutionary materials ***assuming*** their future 'successful implementation.'"). With respect to Knip's disclosure, our review is initially consistent with UTC's position that Knip does not explicitly illustrate either "a first turbine vane," or "a last rotating airfoil stage" as recited in claim 1. As shown in Figures 13 and 14, reproduced above, Knip diagrammatically illustrates a combustor leading to a turbine section, namely a HPT connected via a duct to an LPT. Knip does not illustrate components such as stages, or vanes and blades, of the combustor or turbines in these figures.

The appropriate question, as both parties acknowledge, is not whether Knip expressly discloses these elements, but whether Knip suggests to one of ordinary skill in the art these elements as claimed. *See* Reply 4 ("Knip's schematic allows a POSITA to determine the 'leading edge of a first turbine vane and a trailing edge of the last rotating airfoil' without separately illustrating each vane or rotating airfoil within the engine's turbine section."); *see also* PO Resp. 15–16 ("[T]o prove obviousness, GE must demonstrate how each and every claim feature was either shown or suggested by Knip.") (citing *CFMT, Inc. v. Yieldup Int'l Corp.*, 349 F.3d 1333, 1342 (Fed. Cir. 2003); *Par Pharm., Inc. v. TWi Pharms., Inc.*, 773 F.3d 1186, 1194 (Fed. Cir. 2014)). For the reasons discussed below, we are persuaded that a person of ordinary skill in the art would understand Knip's disclosure to provide sufficient information and detail such that the boundaries of the turbine section between "a first turbine vane" and "a last rotating airfoil stage" can be determined.

Knip illustrates and expressly labels in Figures 13 and 14 an engine flowpath and a turbine section comprised of a HPT and a duct leading to an LPT. Ex. 1006, 6, Figs. 13–14. Knip shows, on scaled drawings, e.g., Figures 13 and 14, the length and diameter of the entire engine flowpath for the baseline engine (Fig. 14) and the advanced engine (Fig. 13), and specifically refers to the various parameters of the advanced engine, including size and weight, in its written description in the related figures and tables. *See, e.g., id.* at 3 ("The purpose of this study was to (1) determine the approximate cycle and configuration for a turbofan engine . . . ."). Also, to undertake its cycle analyses Knip expressly provides for specific numbers of turbine stages for the HPT and LPT. *See id.* at 11 (Table II provides for the HPT having 2 stages, and LPT having 5 stages.). Knip also acknowledges that there are turbine inlet pressures, and therefore turbine inlets, that are considered in the engine cycle analysis. *Id.* at 4 ("[T]urbine inlet turbine inlet temperatures (T41) between 2760 and 3085º R have a small effect on TSFC (fig. 4).").

Referring to Knip's Figures 13 and 14 and various supporting prior art references discussing aircraft turbofan engines, Dr. Attia testifies that a person of ordinary skill in the art "would be very familiar with schematic cross section drawings of turbofan engines and would be able to understand the major structural components and architecture of an engine from a schematic cross section." Ex. 1003 ¶ 21 (citing Ex. 1014, 24–26, Figs. 1–7). Dr. Attia testifies further that "[f]or many decades, the industry standard has been to employ either a one-stage or two-stage HPT in commercial engines." *Id.* ¶ 37 (citing Ex. 1018, 17, 19, 20). Dr. Attia explains that "[a] turbine 'stage' is comprised of a stationary airfoil [(stator vane)] followed by a rotating airfoil [(rotor blade)]. Both airfoils [(vane and blade)] together comprise a single 'stage.'"[7] Ex. 1003 ¶ 69 When asked in his deposition about the lack of an inlet vane being expressly shown in Knip's figures of the HPT, Dr. Attia answered that "[a] person of ordinary skill in the art would know that the inlet of a component is the leading edge of the first airfoil in that component." Ex. 2016, 69:22–70:3. Under further

[7] For consistency of nomenclature we refer mostly to "vanes" as opposed to "airfoils," although the terms appear to be used interchangeably. *See* M. P. Boyce, *Gas Turbine Engineering Handbook* 362 (3d ed. 2006), which describes stationary vanes and moving blades, and states, "[i]n-between the moving rows of blades are guide vanes that redirect the gas from one row of moving blades to another."

questioning by UTC's counsel as to Knip's apparent lack of a "first turbine vane" and what a person of ordinary skill in the art would understand from Knip's turbine section illustration in Figure 13, Dr. Attia was consistent:

> Q: Okay. So turning back to our discussion then of -- of Figure 13 and Knip, either showing or not showing the inlet of a first turbine vane, is it your testimony, sir, that that limitation is missing, the inlet of a first turbine vane?
>
> A: No. It's my testimony that that limitation is present. I discern a vertical line, marking to -- marking the inlet of the HPT component in Knip's Figure 13. To a person of ordinary skill in the art, that would coincide with the leading edge of stator 1 of the first stage in the HPT component.

Id. at 73:8–21. Dr. Attia also referenced prior art which corroborates his testimony. Ex. 1046 ¶ 10 (citing Ex. 1014, 58, Figs. 4–16). Although we appreciate that Dr. Attia acknowledged that the first turbine vane of the HPT was not drawn in Figure 13 (PO Resp. 15), his testimony is unequivocal and confirmed in prior art references. Dr. Attia's testimony is that essentially these turbine components and their relative arrangements were well known, and that a person of ordinary skill in the art would have understood that a boundary of the volume of the turbine section at the "inlet of a first turbine vane," as called for in claim 1, is represented in Knip by the vertical line delineating the forward most part of the HPT in Knip's Figure 13. *See* Ex. 1046 ¶ 5 (Dr. Attia states that "in order to measure the volume of the claimed turbine section in Knip's engine schematic, it is sufficient for a person of ordinary skill in the art ('POSITA') to know where the leading edge of the first turbine vane is located without Knip actually illustrating the first turbine vane.").

UTC counters with testimony from its expert, Dr. Spakovszky, that "Dr. Attia's assertion that Knip shows a 'vertical line' to indicate the beginning of the HPT is simply wrong: there is no vertical line, no matter how much you zoom in on Figure 13." PO Resp. 18 (citing Ex. 2015 ¶ 69). This argument is not persuasive for several reasons. First, UTC's quibble with the visual acuity of "a vertical line" in Knip's figures does not persuasively contradict Dr. Attia's testimony that a person of ordinary skill in the art would have understood that the inlet to the HPT would "coincide with the leading edge of stator 1 of the first stage in the HPT component." Ex. 2016, 67:1–4. Second, whether or not there is in fact "a vertical line" in Figure 13, between the end of the combustor and the inlet to the HPT, there is an observable demarcation, i.e., a boundary, of the end of the combustor and the beginning of the HPT that is shown relative to the scaled drawings along the horizontal Length axis. *See* Ex. 1006, Fig. 13.

Reasonable review and our own perception of Knip's Figure 13 does not persuade us that the demarcation between the combustor and HPT is altogether imprecise, especially relative to the scale and the Length axis. We discern a fairly observable boundary between the combustor and HPT that is reasonably shown on the Length axis between about 92 and 94 inches.[8] Third, GE accounts for measurement error due to this drawing issue. Pet. 35 (citing Ex. 1003 ¶ 110). To account for potential measurement error, in its Petition GE and Dr. Attia offered an error analysis that accounts for measurement error up to 10% in determining the volume of the turbine section. *Id.* Indeed, responding to UTC's "vertical line" and measurement arguments, Dr. Attia provided an updated error analysis and

[8] The enlarged and cropped views of Knip's Figure 13 (PO Resp. 18–19), provided by UTC and Dr. Attia as evidence of the lack of a "vertical line," are not persuasive at least because they don't include the horizontal Length axis also shown in the drawing.

testifies persuasively that "even if I identified the wrong location on Knip's schematic for the boundary between the combustor and HPT, at the absolute most this would have resulted in no more than a 0.90% difference in turbine volume. This is well within the 10% measurement error that I already factored into my calculations." Ex. 1046 ¶ 14 (citing Ex. 1003 ¶ 110).

Continuing to advance its position that one of ordinary skill in the art would not simply assume that Knip's HPT boundary is the "inlet of a first turbine vane," UTC argues that not all turbines include an inlet stator. PO Resp. 22–23. UTC contends that there are multiple prior art examples of vaneless turbines and that "GE and Dr. Attia are therefore wrong that Knip's turbine inlet ***must*** have a vane located coincident with the inlet to the HPT." *Id.* at 22 (citing Ex. 2015 ¶ 70; Ex. 2017, Abstract, ¶¶ 2, 8; Ex. 2018 ¶¶ 1–2, 49–50; Ex. 2019 ¶¶ 19–20, 32, 45; Ex. 2021, Abstract, 1:38–47, 4:38–63, 12:9–14). Our review of these references does show that "vaneless" turbines had been considered, but also that such arrangements are not typical or conventional. For example, U.S. Patent Appl'n Pub. No. 2011/0209482 to Toqan et al. discloses a combustor having corrugations "that turn and accelerate the hot gases to the ideal velocity for the turbine inlet as a typical gas turbine vane nozzle would." Ex. 2017 ¶ 8. By way of another example, U.S. Patent Appl'n Pub. No. 2010/0301617 to Lundbladh explains that different from a conventional turbine, removing the inlet stator "allows the rotation rate of the turbine 24 to have an effect on the gas flow rate." Ex. 2018 ¶ 50. Lundbladh describes that removing the inlet stator is unusual because "[a] conventional turbine inlet stator positioned upstream of the turbine 24, which stator normally is considered to form a part of the turbine." *Id.* ¶ 51. These references provide evidence certainly that there are turbines without stator vanes at the inlet to the turbine. These references are also clear that this arrangement is not typical or conventional. Moreover, these references are explicit in their discussion that a turbine stage normally has, as Dr. Attia testifies, stator vanes followed by rotating blades.

Unlike the references cited by UTC, Knip does not disclose or discuss that its turbine stages are different in any way from a turbine stage as would be normally understood by one of ordinary skill in the art as having a stator followed by a rotor. We are not apprised from these other "vaneless" turbine references that a person of ordinary skill in the art would understand Knip's turbine as having anything but conventional stages with stator vanes followed by rotor blades. Although Dr. Spakovszky asserted in his deposition that "a POSITA cannot just assume that looking at Knip and those figures, that there is a first vane," Dr. Spakovszky admitted that aircraft gas turbine engines typically have inlet stator vanes:

> Q: So as director of MIT's Gas Turbine Laboratory, are you unaware of whether high-pressure turbines in 2012 commonly included a first stator?
>
> A: Typically, commercial gas turbine engines, flying, have first vanes or nozzle guide vanes.

Ex. 1051, 53:14–20, 54:10–12.

The hypothetical person of ordinary skill in the art is attributed with knowledge "of all prior art in the field of the inventor's endeavor and of prior art solutions for a common problem even if outside that field." *In re Nilssen*, 851 F.2d 1401, 1403 (Fed. Cir. 1988). Even knowing that "vaneless" turbines existed, on this record, the evidence is stronger that without some indication of an atypical stage, a person of ordinary skill in the art would most likely understand Knip to describe and suggest a conventional gas turbine stage. The strong evidence in the prior art that a conventional turbine stage typically contains both stator vanes and rotating blades outweighs UTC's argument and Dr. Spakovszky's testimony as to the existence of vaneless turbines. *See e.g.*, Ex. 1005, 48, Fig. 4; Ex. 1014, 58, Fig. 4–16; Ex. 1022, 18, Fig. 15.

We determine that a person of ordinary skill in the art would have understood the forward boundary line drawn in Knip as representative of the "inlet of a first turbine vane" as recited in claim 1. Ex. 1001, 13:31–32. In discerning the scope and content for a particular obviousness reference, the Federal Circuit has been abundantly clear that "obviousness does not require the prior art to teach expressly each limitation exactly." *Beckson Marine, Inc. v. NFM, Inc.*, 292 F.3d 718, 727 (Fed. Cir. 2002). In addition, the Federal Circuit has explained that absent persuasive rebuttal evidence, it is reasonable to rely upon the testimony of a declarant "to support what is 'necessarily present' in a prior art's teaching." *Monsanto Tech. LLC v. E.I. DuPont de Nemours & Co.*, 878 F.3d 1336, 1345 (Fed. Cir. 2018); *c.f. In re Zurko*, 258 F.3d 1379, 1386 (Fed. Cir. 2001) ("With respect to core factual findings in a determination of patentability, . . . the Board must point to some concrete evidence in the record in support of these findings."). Dr. Attia has presented persuasive testimony corroborated by various prior art references that a person of ordinary skill in the art reading Knip's disclosure and analysis of the turbine section, including a HPT having 2 or 3 stages, would have understood Knip to disclose conventional turbine stages, which suggests that each stage, including the first stage of the HPT, includes stator vanes and rotating blades. It is reasonable, therefore, particularly in the absence of compelling rebuttal testimony from Dr. Spakovszky, to determine (a) that from Knip a person of ordinary skill in the art would have understood stator vanes are located at the inlet boundary to the HPT, and (b) rotor blades of a last stage in the LPT determine the exit boundary of the low pressure turbine.

UTC also argues that GE has not shown that a turbine *inherently* has "a first turbine vane." PO Resp. 22–23 (citing *Transclean Corp. v. Bridgewood Servs., Inc.*, 290 F.3d 1364, 1373 (Fed. Cir. 2002)). However, we do not understand that GE is arguing a first stator vane is *inherent* in a turbine, as much as asserting that a person of ordinary skill in the art would understand Knip to disclose conventional turbine stages that typically contain both a stator and a rotor. *See Continental Can Co. v. Monsanto Co.*, 948 F.2d 1264, 1268 (Fed. Cir. 1991) (To establish inherency, the extrinsic evidence "must make clear that the missing descriptive matter is necessarily present in the thing described in the reference."). We do not need to determine whether "a first turbine vane" is necessarily present because we find Knip's disclosure and Dr. Attia's supporting evidence has sufficient basis in fact and technical reasoning such that a person of ordinary skill in the art would understand Knip's HPT stage or stages to include "a first turbine vane" as called for in claim 1.

Overall, despite the level of drawing accuracy and the lack of a specifically illustrated "first turbine vane" and "last rotating airfoil," and the existence of alternative "vaneless" turbines, we are persuaded that a person of ordinary skill in the art, reading Knip in light of its disclosure and with the requisite knowledge and level of skill in the art, would have understood that Knip discloses sufficiently the boundaries of the turbine section between "a first turbine vane" and "a last rotating airfoil stage" as recited in claim 1 of the '751 patent.

c. Whether the Petition sufficiently identified in Knip "a first turbine vane" in accordance with 37 C.F.R. § 42.104(b)(4)

UTC raises the question of whether GE sufficiently identified all the elements of claim 1, namely "a first turbine vane," in its Petition. 37 C.F.R. § 42.104(b) requires, in part, that the Petition must:

> (b) . . . Provide a statement of the precise relief requested for each claim challenged. The statement must identify the following:
>
> . . .
>
> (4) How the construed claim is unpatentable under the statutory grounds identified in paragraph (b)(2) of this section. The petition must specify where each element of the claim is found in the prior art patents or printed publications relied upon.

GE argues in its Petition that Knip discloses in one version of the advanced engine a HPT with two stages, and an LPT having five stages. Pet. 28–29 (citing Ex. 1006, Annotated Fig. 13). The Petition states further that "[e]ach stage contains a turbine rotor and a turbine stator." *Id.* at 30 (citing Ex. 1003 ¶ 96). GE's declarant, Dr. Attia, testifies that "[a] turbine 'stage' is comprised of a stationary airfoil [(stator vane)] followed by a rotating airfoil [(rotor blade)]. Both airfoils [(vane and blade)] together comprise a single 'stage.'" Ex. 1003 ¶ 69. To meet the limitations in claim 1 of "a first turbine vane" and "a last rotating airfoil," which define the claimed "volume of the turbine section," we understand that GE is expressly relying on the illustrated boundaries of the HPT and the LPT as coinciding with these claim elements. *See* Pet. 31 (GE argues that using Knip's Figure 13, "[a] POSITA would also have been able to calculate the volume of the turbine section disclosed by Knip." (citing Ex. 1003 ¶¶ 106–111)). In addition, the Petition explains that Knip expressly discloses that HPTs and LPTs can include multiple stages and that each stage includes a stator and a rotor. *Id.* at 30. The Petition states for example, that because "[e]ach stage contains a turbine rotor and a turbine stator – therefore, the five stages disclosed means that there are five LPT rotors." *Id.* (citing Ex. 1003 ¶ 96). Also, in the claim construction section, the Petition discusses the meaning of "the volume of the turbine section" as including a first turbine vane in the HPT, and a last rotating airfoil in the LPT. *Id.* at 21 (citing Ex. 1003 ¶¶ 69–71). To support this construction, the Petition relies on an example by Dr. Attia, who testifies that "a POSITA would understand that the exit of a turbine stage is typically a rotating airfoil . . . which typically marks the 'end' of a stage." Ex. 1003 ¶ 71.

UTC's argument is not lost on us here. We do not find in the Petition or Dr. Attia's initial declaration an express statement, for example, that the entrance of Knip's HPT would have been understood by a person of ordinary skill in the art to define, as it was typically known to be, the inlet of a first turbine vane. The Petition presumed, to some extent, that all the preliminary discussion and background on turbines and stages, including stator and rotor components, along with the knowledge of a person of skill in the art relating to turbine section components and volume, sufficiently identified "a first turbine vane" as recited in claim 1.

We find GE's lack of a full-throated explicit correspondence of this claim limitation to Knip as not prejudicial of the challenges in this case. For one thing, as discussed above, it is clear from the Petition and Dr. Attia's testimony that a turbine stage containing a stator and rotor is conventional and not a novel development in gas turbine engine technology. *See, e.g.*, Pet. 46 n.9, *see also* Ex. 1014, 59, Figs. 4–17(a)–(b). GE supplemented Dr. Attia's testimony with a second declaration that expressly states that, based on a typical turbine stage having a stator and a rotor, a person of ordinary skill in the art "would have naturally understood that the 'beginning of the HPT,' *i.e.* the most forward boundary of the HPT, coincides with the leading edge of the first turbine vane in the HPT because this is the first component portion of the HPT to come into contact with the hot gas-flow that exits the combustor." Ex. 1046 ¶ 9.

Regardless of Dr. Attia's second declaration, we determine that the Petition is not deficient as to an explanation for the claimed "inlet of a first turbine vane." The Petition identified specific portions of the evidence, e.g., the illustrated boundaries of Knip's HPT and LPT, the disclosure of multiple stages in an HPT and LPT in Knip, and that a stage typically includes a stator and a blade. Pet. 28–36 (citing Ex. 1003 ¶¶ 95–96, 106–111; Ex. 1006, 6).

We determine that these illustrated boundary elements in Knip as relied upon in the Petition are linked sufficiently in the context of the Petition, as well as by the level of ordinary skill and knowledge in the art, as corresponding with the claimed limitation of "an inlet of a first turbine vane." *See* Pet. 31 ("Specifically, Figure 13 in Knip provides a scaled two-dimensional cross section of the engine's flow path, which a POSITA would have known provides the information necessary to calculate the turbine section volume."). Although it could have been stated more explicitly, a reasonable reading of the Petition conveys that the first stator vane of the first stage of the HPT, just like the last rotating blade of the last stage of the LPT, defines the illustrated axial boundaries of Knip's turbine section along the length of the horizontal axis in Knip's Figure 13. *See* Ex. 1003 ¶ 71 (Dr. Attia testifies that "a POSITA would understand that the exit of a turbine stage is typically a rotating airfoil, so the broadest reasonable interpretation of the 'last rotating airfoil stage' is the last airfoil that rotates, which typically marks the 'end' of a stage."). Consequently, we are persuaded that the Petition adequately specifies that the forward boundary of the HPT would have been understood by one of ordinary skill in the art as the "inlet of a first turbine vane" as recited in claim 1, and accordingly meets the requirements of 37 C.F.R. § 42.104(b).

d. Whether Knip's Figure 13 lacks sufficient detail to determine "power density"

Claim 1 recites in part:

> *a power density* at Sea Level Takeoff greater than or equal to 1.5 lbf/in^3 and less than or equal to 5.5 lbf/in^3 and defined as thrust in lbf measured by a volume of the turbine section in in^3 measured between an inlet of *a first turbine vane* in said second turbine to an exit of *a last rotating airfoil stage* in said fan drive turbine.

Ex. 1001, 13:28–31 (emphases added). UTC argues that Knip fails to disclose sufficient detail to determine "power density," as recited in claim 1. PO Resp. 23. This argument is essentially an extension of its assertions above, that "Knip's figures do not show—much less 'clearly' show—the 'first turbine vane' and 'last rotating airfoil stage' required by the Challenged Claims." PO Resp. 24 (citing Ex. 2015 ¶ 69). UTC argues specifically that "Knip's Figure 13 was plainly ***not*** intended to show the dimensions of a turbine section volume 'measured between an inlet of a first turbine vane in said second turbine to an exit of a last rotating airfoil stage.'" *Id.* The question however, is not what Knip's figures "intended" to show, but what would have been understood from Knip's figures and description by a person of ordinary skill in the art. Obviousness is not determined from the perspective of the inventors or authors of a prior art reference. Rather, obviousness is determined from the perspective of a hypothetical person having ordinary skill in the art. It is only that hypothetical person who is presumed to be aware of all pertinent prior art. *Standard Oil Co. v. Am. Cyanamid Co.*, 774 F.2d 448, 454 (Fed. Cir. 1985).

As discussed above, Dr. Attia explained that although the first turbine vane of the HPT was not drawn in Figure 13, a person of ordinary skill in the art would have understood that the left-most boundary of the volume of the turbine section at the "inlet of a first turbine vane," as called for in claim 1, was shown in Knip by the vertical line delineating the forward-most part of the HPT in Knip's Figure 13. Ex. 1003 ¶¶ 69–71; Ex. 2016, 65:19–67:4. Also, we determined above based on Dr. Attia's testimony and measurement error analysis that the clarity and relative scale of the drawings would have been sufficient for one of ordinary skill in the art to determine that the demarcation between the combustor and HPT is reasonably shown on the Length axis. *See* Ex. 1003 ¶ 106 ("[A] POSITA would have also known how to use available software tools to reverse-engineer the two-dimensional slice disclosed by Knip, convert it into a three-dimensional model, and calculate the resulting flowpath volume."); Ex. 2016, 65:19–67:4.

UTC argues further that Knip describes and illustrates only a "conceptual design phase" of an advanced engine and not enough detail to actually determine the turbine section volume. PO Resp. 23 (citing Ex. 2015 ¶¶ 57, 66–68). Dr. Spakovszky testifies that "[t]hough Knip mentions blades and vanes, it does so only in order to define the pressures, temperatures, and efficiencies used as input data for the 'black box' models of the components." Ex. 2015 ¶ 68. Knip's advanced engine design may be "conceptual" as UTC argues, but we find GE's evidence more persuasive. Knip's figures offer specific, detailed, scaled comparisons showing the dimensions (Radius and Length in in^3) of the advanced engine and its major components. *See* Ex. 1006, Figs. 13–14. UTC's argument and supporting testimony are largely contradicted by the clearly illustrated relative scale, (in^3) and Length-Radius axes, in Knip's Figure 13 that illustrate the dimensions of the advanced engine. We agree that the scaled drawing in Knip's Figure 13, as Dr. Attia persuasively testifies, "provides the dimensions of the flow path in each section of the engine, as well as the relative position of the components with respect to each other." Ex. 1003 ¶ 92.

UTC relies on various case law and contends "that figures or drawings in a prior art reference may only be relied upon for what they '***clearly*** show.'" PO Resp. 23–24 (citing *Hologic, Inc. v. SenoRx, Inc.*, 639 F.3d 1329, 1338–39 (Fed. Cir. 2011); *In re Seid*, 161 F.2d 229, 231 (CCPA 1947); *In re Wagner*, 63 F.2d 987, 988 (CCPA 1933)). In *Hologic*, the Federal Circuit found that a prior art hand-drawn figure "does not clearly show asymmetry" and was not convincing evidence of invalidity. *Hologic*, 639 F.3d at 1339. As discussed above, we are persuaded on the compelling facts and evidence presented by GE that Knip's scaled drawing does show clearly to an ordinary artisan that the volume of the turbine section in Figure 13 can be determined "in in^3 measured between an inlet of a first turbine vane in said second turbine to an exit of a last rotating airfoil stage in said fan drive turbine," as called for in claim 1.

e. Whether Dr. Attia's SLTO thrust values are too low

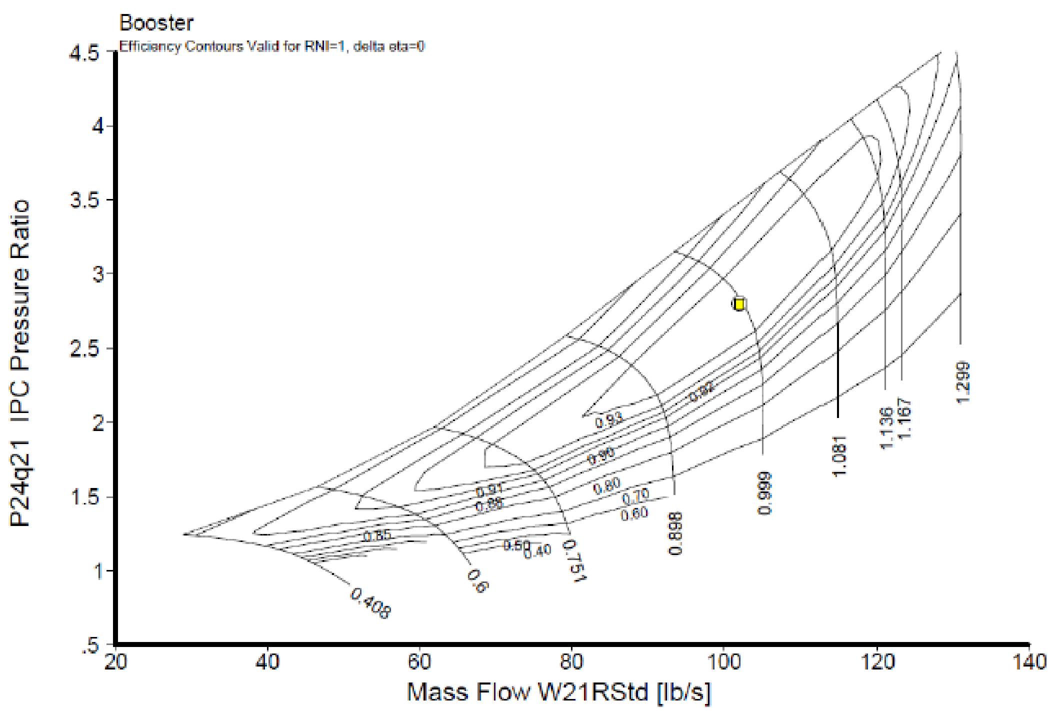
UTC argues that Dr. Attia's estimates of SLTO thrust are too low, and therefore his "power density" calculations are incorrect. PO Resp. 25. UTC offers two reasons why Dr. Attia's estimates are too low: first, UTC argues that "Dr. Attia's SLTO thrust values are far too low to satisfy Knip's stated mission of an intercontinental quadjet with a range of 5500 nmi and a payload of 500 passengers," and second, "Dr. Attia overlooked clear teachings of how to properly perform the estimation." *Id.* at 25–26 (citing Ex. 2015 ¶¶ 35–50). Below, we summarize Dr. Attia's calculations as to SLTO thrust, and then consider these calculations in light of UTC's arguments that they are incorrect, and are too low.

Dr. Attia testifies that to determine engine thrust in Knip's advanced engine a person of ordinary skill in the art would have used the given engine parameters in Knip as inputs into a computer program such as GasTurb 9. Ex. 1003 ¶ 99. Thus, Dr. Attia uses *inter alia* Knip's express cruise altitude thrust engine parameters, e.g., Mach 0.8 and 10,000 lb thrust at 35,000 ft. (not the range and payload aspects of an intercontinental quadjet), as well as several estimates of parameters, for example component efficiencies that were not provided, to initially determine a more complete engine model for the given cruise altitude operating conditions in Knip: .8 Mach and 10,000 lb thrust at 35,000 ft. *See id.*, App'x A ¶ 1 ("For values that are needed but not specifically stated, I used basic engineering calculations and judgement and justified the choices as described below."). With a more complete engine model based on the cruise thrust and altitude (the "on-design" model) determined through using GasTurb 9, one can then essentially work backwards to determine the SLTO thrust (the "off-design" model) of Knip's engine. *See id.*, App'x A ¶¶ 2, 11.

A first step for Dr. Attia in determining the on-design model was to determine the appropriate volume for the advanced engine and its components using DataThief III, for example to calculate the fan inlet area from Knip's Figure 13. Given the fan inlet area, Dr. Attia then determined the known parameter of corrected mass flow rate at the fan inlet. *Id.*, App'x A ¶ 5. Dr. Attia next accounted for pressure losses and component efficiencies of non-working components (e.g., fan inlet, nozzles, ducts). At the fan inlet for instance, Dr. Attia determined based on Knip's values given in Table III, that "the inlet duct induced a 1.4% total pressure loss, which is a very reasonable [first estimate] value for an advanced engine inlet duct." *Id.*, App'x A ¶ 6.

To determine the adiabatic efficiencies of the working components (e.g., fan, compressor, turbines) in Knip's engine, Dr. Attia corrected values from the enthalpy-entropy diagram, i.e., the Mollier Diagram, with pressures and temperatures from Knip's Table III. *Id.*, App'x A ¶ 7. For example Dr. Attia calculated that the low pressure compressor (LPC) efficiency is 91.8% and that a person of ordinary skill in the art "would recognize that efficiency values in the low 90's, such as 91.8%, is in line with what would be expected of advanced turbofan components in Knip's timeframe, *i.e.,* the late 1980's." *Id.*, App'x A ¶ 7. In determining this efficiency, Dr. Attia also addressed the correction of the given LPC pressure ratio of 2.8 from Table III, which provided an impossible efficiency, to a LPC pressure ratio of 2.543 based on the given inlet and outlet pressure across the LPC also set forth in Table III. *Id.* Dr. Attia next calculated the petal angle of the bypass nozzle and core nozzle "to finalize the thrust calculations by determining the nozzle discharge coefficient." *Id.*, App'x A ¶ 8. Dr. Attia then used these input values in GasTurb 9 to produce a table that "represents the output of the GasTurb model at cruise conditions, which are 0.8 Mach and 35,000 ft." *Id.*, App'x A ¶ 9. With the on-design model now complete, Dr. Attia testifies that the GasTurb 9 "values match the given parameters by Knip including [by-pass ratio], Overall pressure ratio, Thrust, pressures and temperatures from Table III, as well as the calculated mass flow rate." *Id.*

To determine the off-design model, i.e., the SLTO model, Dr. Attia approximated the gear ratio between the fan and LPC using DataThief III to determine the fan tip radius and the LPC tip radius from Knip's Figure 13. *Id.*, App'x A ¶ 11. From this, the rotational tip speeds of 2,304 rpm for the fan and 11,058 rpm for the LPC were determined and the gear ratio was estimated to be 4.8:1. *Id.* According to Dr. Attia, "[t]he final step is to model the off-design performance by scaling the default component maps for the fan, LPC, HPC, HPT, and LPT." *Id.*, App'x A ¶ 12. Dr. Attia used GasTurb 9 to produce engine component maps, for example an LPC map, shown below.



Generic LPC Map in GasTurb Showing Peak Performance Set at Cruise

The GasTurb 9 LPC map above shows LPC pressure ratio versus mass flow, and illustrates the design point, in yellow, chosen by Dr. Attia to be near the point of peak efficiency. *Id.*

With the off-design model now set up, Dr. Attia ran GasTurb 9 to determine the off-design thrust at SLTO conditions. *Id.*, App'x A ¶ 13. Dr.

Attia explained for SLTO conditions in GasTurb 9 "[t]he flight speed is set to 0.2 Mach as is customary for Take-Off, and the turbine inlet temperature remains at 3085 °R, same as climb and cruise." *Id*. We note that Dr. Attia also raised the component efficiencies of the compressor and turbine higher to account for the advanced design of the engine. *Id.*, App'x A ¶ 1.C ("I modified the compressor and turbine efficiencies higher (from a baseline value) to account for advanced designs. I did this by increasing the component efficiencies by 1% and then again by another 1%. This resulted in higher SLTO values as was expected."). With these 1% increments to the component efficiencies, Dr. Attia testifies that "[t]he increased thrust values were computed by GasTurb to be 28,474 lbf and 30,524 lbf." *Id.*, App'x A ¶ 14.

UTC argues that Dr. Attia's thrust values determined by the on-design, and subsequent off-design SLTO analysis, "are far too low to satisfy Knip's stated mission of an intercontinental quadjet with a range of 5500 nmi and a payload of 500 passengers." PO Resp. 25 (citing Ex. 2015 ¶¶ 21–40; Ex. 1006, 3). In support of this argument, UTC points to Knip's express reliance on the Gray-1 and Gray-2 references "and the nearly-identical mission requirements of the Knip and Gray-2 engines." [9] *Id.* at 29. UTC argues that Table 5.3 in Gray-2 specifically shows that the SLTO for the

[9] As Referenced by Knip, (Ex. 1006, 10) Grey 1 is NASA Contract Document by, Gray, D.E., titled, Energy Efficient Engine Preliminary Design and Integration Study. (PWA-5500-18, Pratt and Whitney A l r c r a f t ; NASA Contract NAS3-20628) NASA CR-135396, 1978. Grey 2 is NASA Contract Document by Gray, D.E. and Gardner, W.B., titled Energy Efficient Engine Program Technology Benefit/Cost Study, Vol. 2, (PWA-5594-251-VOL-2, Pratt and Whitney Aircraft; NASA Contract NAS3-20646) NASA CR-174766-VOL-2, 1983.

same advanced engine would be greater than 40,000 lbf in each example disclosed. *Id.* at 30–31 (citing Ex. 2015 ¶ 32; Ex. 2042, 97–100). UTC argues that Gray-1 similarly "discloses five example engines for 'the long range international' quadjet with 42,000 lbf or greater of SLTO thrust." *Id.* at 31 (citing Ex. 2012, 103).

GE responds, asserting that although the mission requirements are the same between Knip, Gray-1, and Gray-2, Knip is a different engine and "incorporates 'advanced composite materials throughout the engine,' as well as 'structural changes such as swept fan and compressor blades, uncooled turbines, reduced hub tip ratios, higher blade loadings, reduced clearances, and three-dimensional design concept.'" Reply 16 (citing Ex. 1006, 2). GE's response is persuasive for several reasons. The idea that an engine's SLTO thrust is based only on passenger payload and range ignores the engine itself. In other words, UTC's argument presupposes a result, namely that in order to carry 500 passengers and fly 5,500 nautical miles, an engine must provide 40,000 lbf thrust at takeoff. *See* PO Resp. 25–26 (citing Ex. 2015 ¶¶ 21–40; Ex.1003 ¶ 46; Ex. 1006, 3). But as GE argues, this would defeat the entire purpose of having a lighter more efficient engine that needs less fuel to fly a lighter aircraft farther. Reply 16. Dr. Attia explains that aircraft payload and range parameters are not sufficient to determine engine SLTO thrust because a person of ordinary skill in the art "would not have presumed Knip's SLTO thrust based on these parameters alone. Instead, . . . a POSITA would have performed a cycle analysis, like I did, to calculate Knip's SLTO thrust." Ex. 1046 ¶ 20. Dr. Attia testifies that aircraft frames and engines are generally designed in relative conjunction, and that

> Knip's more efficient, lighter engine will require a smaller wing and support structure to carry its engine and the fuel it requires,

> as well as less fuel due to its improved efficiency, resulting in a lower take-off weight and, ultimately, a reduced SLTO thrust.

Id. ¶ 23. In other words, we find GE's position persuasive, as supported by Dr. Attia's testimony, that reducing engine weight and increasing engine efficiency can result in smaller airframe size and weight, as well as lower the amount of fuel necessary to fly a desired distance. It is reasonable to understand, therefore, that less SLTO thrust would have been required for an appropriately designed aircraft and its mission requirements. *See id.* (Dr. Attia testifies that "it is entirely expected that Knip's SLTO thrust, when mated with a suitable aircraft that is designed to take advantage of Knip's stated advantages, would be ***lower*** than the aircrafts disclosed by Gray-1, Gray-2, and Wendus (Ex. 1025).").

In addition, Knip relies on Gray-1 and Gray-2 mainly for its baseline comparison engine, not the advanced engine per se. *See* Ex. 1006, 3 ("The baseline engine used for the study is similar to the Maximum Efficiency Energy Efficient Engine of reference 4.").[10] Knip expressly states that the advanced engine analyzed in Knip is different, having

> higher component efficiencies due to the use of advanced composite materials were postulated based on components having thinner blades, higher tip velocities, uncooled turbines, improved clearance control, and reduced hub-tip ratios in addition to making more efficient use of advanced three-dimensional, CFM design technology.

Id. We give weight to GE's arguments and evidence, which explain persuasively why the advanced engine SLTO thrust would be lower than that necessary for prior aircraft, even keeping in mind similar aircraft mission

[10] Reference 4 in Knip's "References" section is the Gray-2 reference.

requirements such as passenger payload and flight distance between Knip and Gray-1 and Gray-2.

f. Whether Dr. Attia's estimates and assumptions such as Turbine Inlet Temperature (T_4) in his SLTO analysis are incorrect

UTC argues that another reason GE's SLTO thrust values are too low "is that Dr. Attia's assumptions were wrong." PO Resp. 36. UTC attacks Dr. Attia's assumption that the turbine inlet temperature (T_4) of 3,085 °R should remain the same in the engine analyses for both cruise altitude in the on-design analysis, and also the SLTO off-design analysis. *Id.* at 38–39. UTC argues that Dr. Attia disregarded the express teaching in the GasTurb 9 Manual, which for SLTO "teaches that a user should ***increase*** the T_4 temperature when calculating the 'hot day' (i.e., flat rated) thrust." *Id.* at 39 (citing Ex. 1003, 133–34, ¶ 13; Ex. 2015 ¶ 37). Corresponding to the "hot day" turbine inlet temperature discussed in the GasTurb 9 Manual, UTC contends that Dr. Attia also failed to account for the fact that Knip itself teaches an upper limit for T_4 of 3,460 °R based on materials properties. In support of these arguments, Dr. Spakovszky testifies that the assumption that "T_4 remain constant from design to off-design introduced a significant error in [Dr. Attia's] model, and it resulted in his SLTO estimates being far lower than the 40,000+lbf that is required for Knip's 500-passenger international quadjet to takeoff." Ex. 2015 ¶ 40; PO Resp. 40–41.

GE disputes these assertions and contends that "hot day" thrust described in GasTurb 9 is a condition that considers "above-normal temperatures" and "is not the same as SLTO thrust." Reply 20 (citing Ex. 1046 ¶ 34). GE points out that the claims of the '751 patent do not require SLTO thrust to accommodate "hot day" values. *Id.* (citing Ex. 1036, 178; Ex. 2051, 92:15–22). GE also responds by having Dr. Attia perform his SLTO off-design analysis using the GasTurb 9 Manual's proscribed "hot day" ambient temperature (ISA+15K), and increasing the off-design T_4 by 100K (180 ºR). *Id*. According to GE, Dr. Attia "still obtained a SLTO thrust of 27,284.39 lbf, which corresponds to a power density within the claimed range: 4 to 4.9 lbf/in^3." *See id.*, *see also* Ex. 1046, 38.

We note that although the GasTurb 9 Manual does discuss the importance of "hot day take off" thrust as UTC argues, it is also consistent with GE's position as the GasTurb 9 Manual states that "[n]ot every day is a hot day with an ambient temperature of 30°C (86°F) or higher. The peak burner exit temperature is therefore seldom used." Ex. 1036, 178. Thus, we find that the GasTurb 9 Manual does not show unambiguously that "hot day" take-off thrust *must* be considered in all SLTO engine analyses. Regardless, Dr. Attia reiterated his analysis increasing the T_4 temperature by 180 °R, to 3,265 °R, for "hot day" conditions as discussed in the GasTurb 9 Manual, which still resulted in a thrust of 4.0 to 4.9 lbf/in^3, values still within the claimed power range. Ex. 1046 ¶ 38. Dr. Attia's additional "hot day" calculation here, based on GasTurb 9's "hot day" parameters, is consistent with other exemplary engines that UTC argues are relevant. For example, UTC points out that in the Wendus reference the engine has a "T_4 of 3560 ºR at takeoff and 3443 ºR at max climb." PO Resp. 38 (citing Ex. 1025, 17, Figs. 3–4). That is, in Wendus, the T_4 temperature difference of 117 ºR is even less than the temperature difference (180 ºR) discussed by the GasTurb 9 Manual.

Disputing Dr. Attia's off-design T_4 estimate, UTC argues further that Knip teaches "to set the T_4 at takeoff toward the upper limits of the turbine blade materials." PO Resp. 40 (citing Ex. 2010, 24–29). According to UTC a person of ordinary skill in the art "would have known to utilize a T_4 of

3460 °R when approximating the SLTO of Knip's engine, instead of holding the value constant as Dr. Attia did." *Id.* (citing Ex. 2015 ¶ 40).

Dr. Attia disagrees, stating that a person of ordinary skill in the art would not set T_4 at the materials limit, "which would have risked damaging the turbine." Ex. 1046 ¶ 42. Dr. Attia testifies, pointing to Figure 5.5 in the Crumpsty reference, that around the priority date of the '751 patent a person of ordinary skill in the art "would have more likely determined that the upper limit for turbine ceramics was closer to 1,850 K, which corresponds to 3,330 °R." Ex. 1046 ¶ 43 (citing Ex. 2010, Fig. 5.5). Given this, Dr. Attia then reiterated his SLTO analysis, setting off-design T_4 to 3,330 °R, and determined "Knip's SLTO thrust to be 30,519.65 lbf, which corresponds to a power density of 4.5 to 5.5 lbf/in^3 – still within the claimed range." *Id.* Finally, addressing Dr. Spakovszky's specific assertion that off-design T_4 should be 3,460 °R, Dr. Attia reiterated his SLTO analysis setting T_4 to 3,460 °R and "calculated an SLTO thrust of 36,890 lbf, which corresponds to a power density of 5.4 to 6.7 lbf/in^3." *Id.* ¶ 44. According to Dr. Attia, this determination thus includes values within the power density range recited in claim 1.

We also consider the testimony and analysis by Dr. Spakovszky that also sets T_4 at 3,460 °R, and obtains a different, much higher, power density than Dr. Attia's calculations, one that is outside the claimed range. PO Resp. 42–44 (citing Ex. 2015 ¶¶ 46–52). Contrary to Dr. Attia's analysis, Dr. Spakovszky determined that Knip's "range of power densities is between 8% and 73% higher than the power density range recited in the Challenged Claims." Ex. 2015 ¶ 54. The difference between Dr. Attia's and Dr. Spakovszky's analyses, although both use GasTurb 9 and similar methodology, is that the experts do not use, and in fact do not agree on, the same assumptions and estimates for certain engine parameters used in the GasTurb 9 analyses. Besides disagreeing on "hot day" considerations and T4 temperatures to conduct their experiments, Dr. Spakovszky increases the component efficiencies higher than Dr. Attia's SLTO off-design model, and also asserts that Dr. Attia's "map scaling results in unacceptable stability margins at off-design conditions." Ex. 2015 ¶¶ 42–45.

Before us is a clear conflict between expert testimony, essentially as to how best to model Knip's engine and specifically what would be the better estimated values of certain parameters and variables for modeling the advanced engine. For example both Dr. Attia and Dr. Spakovszky agree that component efficiencies are important to modeling and determining engine performance. *Compare* Ex. 2015 ¶ 42, *with* Ex. 1003, App'x A ¶ 12. Each expert applies different values to these parameters, such as Dr. Attia estimated design point efficiencies near to peak efficiency from the scaled default component maps of the engine components. *See* Ex. 1003, App'x A ¶ 12 (Dr. Attia explains that "[a]dditional user input is required to choose the location of the design point efficiencies on the generic map. If improperly chosen, the off-design efficiencies will be unrealistically high (above 1 in some cases)."). Whereas Dr. Spakovszky contends that "Dr. Attia's map scaling results in unacceptable stability margins at off-design conditions." Ex. 2015 ¶ 45.

The experts certainly disagree with one another, but what neither makes entirely clear for us is why their colleague's estimates are entirely wrong. On one hand Dr. Spakovszky fails to explain why Dr. Attia's chosen efficiency from the scaled default component maps near to peak design point efficiency do not offer sufficient operability margins. *See id.* (Dr. Spakovszky states that "Dr. Attia's map scaling results in unacceptable stability margins at off-design conditions.”). On the other hand Dr. Attia does not clarify why Dr. Spakovszky’s component pressure ratios with lower stability margins than his (Dr. Attia’s) model are in error. *See* Ex. 1046 ¶ 53 (Dr. Attia states “it is clear that Dr. Spakovszky’s model utilizes component pressure ratios with considerably lower stability margins than my model.”).

We resolve the conflict in this case by crediting both Dr. Attia’s and Dr. Spakovszky’s analyses. Estimates and assumptions are by their very nature imperfect. Both experts repeat their analyses using various estimates to attain what they each contend is a more accurate “power density.” *See* PO Resp. 44 (UTC argues that “a more accurate estimation of Knip’s ‘power density’ would be well above the claimed range.”), *see also* Reply 20 (GE argues that “Dr. Spakovszky erroneously increases three input parameters in his GasTurb simulation, resulting in an unreasonably inflated SLTO thrust calculation for Knip’s engine.”). Both Dr. Attia and Dr. Spakovszky have submitted conclusions based on their experience and presented reasoned technical explanations evidenced, at least some extent, by the supporting references. Having assessed the evidence, analyses, and credibility of both experts, we find it difficult on this record without resorting to evidentiary or legal pretense to ascertain whose estimates are more accurate and credible. We determine that a person of ordinary skill in the art would have been able to apply a variety of estimated values in the GasTurb 9 program as both Dr. Attia and Dr. Spakovszky have done. In other words, Dr. Spakovszky’s higher thrust values, and hence higher ranges for power density do not convince us that Dr. Attia’s estimates of Knip’s engine parameters leading to a lower thrust value are unreasonable or overtly inaccurate. Overall, we are persuaded that a person of ordinary skill in the art using the estimates and assumptions proposed in Dr. Attia’s analyses of Knip’s advanced engine would have obtained values for "power density" within the claimed range set forth in claim 1.

g. Whether "power density" is a result effective variable

GE argues that the claimed engine characteristic "power density" is a result effective variable, well known to those of ordinary skill in the art and therefore obvious, even if referred to in claim 1 under the guise of a newly coined term. Pet. 36 (citing Ex. 1003 ¶¶ 72–87, 112). GE asserts that "power density" is simply the result, i.e., the ratio, of the known relationship between SLTO thrust and the volume of the turbine section and that the '751 patent does not indicate in any manner that the range is unexpected. *Id.* at 37. GE argues that "it is not inventive to discover the optimum or workable range of a result-effective variable by routine experimentation unless the claimed range produces unexpected results." *Id.* (citing *In re Applied Materials, Inc.*, 692 F.3d 1289, 1295–97 (Fed. Cir. 2012)).

UTC disputes that "power density" is a result effective variable. PO Resp. 67. UTC draws our attention to that fact that during the prosecution of patent applications related to the '751 patent, the Examiner initially determined that "power density" was a result effective variable, and yet the Board subsequently reversed the Examiner's finding. *Id.* According to Patent Owner, in appeals of the related applications the Board determined that the reference to Dev (Exhibit 1032 in this proceeding) shows a graph relating the *entire* engine volume (cu. ft.) to rated thrust (lbf), not *turbine volume*, and therefore disclosed a different parameter than that recited in the claims. *See Ex parte Schwarz*, Appeal No. 2017-002377, at 4–8 (PTAB Feb. 23, 2018); *see also Ex parte Schwarz*, Appeal No. 2017-002075, at 4–6

(PTAB Feb. 2, 2018).[11] UTC argues that in view of these Board decisions, Dev, therefore, does not establish "power density" as a result-effective variable. On the evidence and testimony now before us, we disagree.

In *Schwarz*, the Board determined that

> the Examiner appears to presume that changes in engine volume will result in proportional volume changes across the turbine, compressor, and combustor sections. However, as indicated above, the Examiner does not explain how a change in engine volume could not also encompass a disproportionate effect on the volume of these three sections. In effect, one skilled in the art, viewing Dev's changing engine volume, would have to guess at what the turbine section volume might be.

Schwarz, at 6. Thus, in *Schwarz* the Board found that the Examiner had made an unsupported factual finding. UTC's reliance on the Board's appeals decisions in *Schwarz* is misplaced because in this proceeding we have testimony from Dr. Attia essentially confirming the Examiner's original finding that a person of ordinary skill in the art would have understood from Dev that "the claimed thrust to turbine volume ratio was a known result-effective variable" Ex. 1003 ¶ 74.

As discussed in even further detail below, Dr. Attia explains that proportionally, the engine volume can only be known if turbine volume is known and that "[a] POSITA would readily understand that turbine volume is a subset of engine volume, and that Dev's disclosure of the relationship between force to engine volume similarly indicates that the relationship between force to turbine volume is also a result effective variable." *Id.* ¶ 75. Also, UTC's opposition consists entirely of attorney argument and provides no substantive evidence or testimony for us to consider refuting Dr. Attia's

[11] Because the appeals are similar, further citations refer only to *Ex Parte Schwarz*, Appeal No. 2017-002075 (PTAB Feb. 2, 2018) ("*Schwarz*").

position. PO Resp. 67–68. On the record in this proceeding, which includes evidence and testimony not before our colleagues in *Schwarz*, we credit Dr. Attia's testimony that a person of ordinary skill in the art would have understood from Dev that proportionally, "the relationship between force to engine volume similarly indicates . . . the relationship between force to turbine volume." Ex. 1003 ¶ 75.

It is well-settled that a result effective variable is a variable, i.e., a value, characteristic, or property, that is recognized in the prior art and by those of ordinary skill in the art, which can be altered, changed, and experimented with to achieve a desired outcome. *See Application of Aller*, 220 F.2d 454, 456 (CCPA 1955) (The court explained that for a combination of known chemicals "[n]ormally, it is to be expected that a change in temperature, or in concentration, or in both, would be an unpatentable modification."). For a variable that is result effective, making changes or optimizing such a variable, is quite often obvious to a person of ordinary skill in the art. *See In re Applied Materials, Inc.*, 692 F.3d 1289, 1297 (Fed. Cir. 2012) ("Nothing indicates that the optimization of the variables was anything other than the exercise of ordinary skill in the art."). There are exceptions, for example where unexpected results of optimizing a variable are achieved. *See Application of Antonie*, 559 F.2d 618, 620 (CCPA 1977) (The court explained that one exception is "where the results of optimizing a variable, which was known to be result effective, were unexpectedly good."); *see also Applied Materials*, 692 F.3d at 1297 (The Federal Circuit explained that "a prima facie case of obviousness established by the overlap of prior art values with the claimed range can be rebutted by evidence that the claimed range is 'critical' because it 'achieves unexpected results.'").

It is undisputed in this proceeding that the numerator and denominator (engine thrust and turbine volume) of the claimed "power density" ratio are themselves known variables in the art that achieve a recognized result, and hence, result effective variables. PO Resp. 67–68; Reply 28; MPEP § 2144.05(II)(B). As explained in the Specification of the '751 patent, "power density . . . may be defined as thrust in pounds force (lbf) produced divided by the volume of the entire turbine section 28." Ex. 1001, 10:23–25. Consistent with the Specification, claim 1 recites "power density" as a ratio of (a) SLTO thrust (lbf) as a function of (b) turbine section volume (in^3). *See* Ex. 1001, 13:28–31. Claim 1 further recites a specific range of values for power density being "greater than or equal to 1.5 lbf/ in^3 and less than or equal to 5.5 lbf/ in^3." *Id.*

One of UTC's arguments is essentially that the '751 patent is the first to define "power density," i.e., determined the result, or ratio, of SLTO thrust with respect *to turbine section volume*. *See* PO Resp. 67 (UTC argues that GE's "arguments fail to apply the specific volume definition of the'751 Patent claims—which recites a specific ***turbine section*** volume, not the volume of an ***entire engine***."). According to UTC, Dev's Figure 22, which illustrates graphically engine thrust as a function of engine volume, does not render "power density" obvious because the claimed "volume of the turbine section" is a different parameter than the entire engine volume graphically depicted in Figure 22 of Dev. *See id.*; *see also* Ex. 1001, 11:18–22 (Discussing power densities shown in Table 1 of the '751 patent, the Specification states that "[e]ngines made with the disclosed architecture, and including turbine sections as set forth in this application . . . provide very high efficient operation, and increased fuel efficiency and lightweight relative to their thrust capability.").

For the reasons below, we determine that "power density" is a result effective variable.

We note that the term "power density" is not a new term for describing the efficiency of a gas turbine engine. Ex. 1032, 2:2–11. Dev states that "amongst the objects of the present invention is to provide a lightweight/high-*power density* engine." *Id.* at 2:2–3. Dev further explains that an engine efficiency goal is "offering higher power/weight compared to current gas turbine engines of conventional design." *Id.* at 2:9–11. Dev's figure description states that "FIGS. 22–23 are graphs respectively illustrating thrust versus engine volume . . . for field engines of the prior art and gas turbine engines of the present invention." *Id.* at 3:31–35.

It is clear from Dev's Figure 22, reproduced below, that engine thrust, including SLTO thrust, as well as the volume of the engine as a whole, including the turbine section volume, are known and related variables in the art relating to engine efficiency.

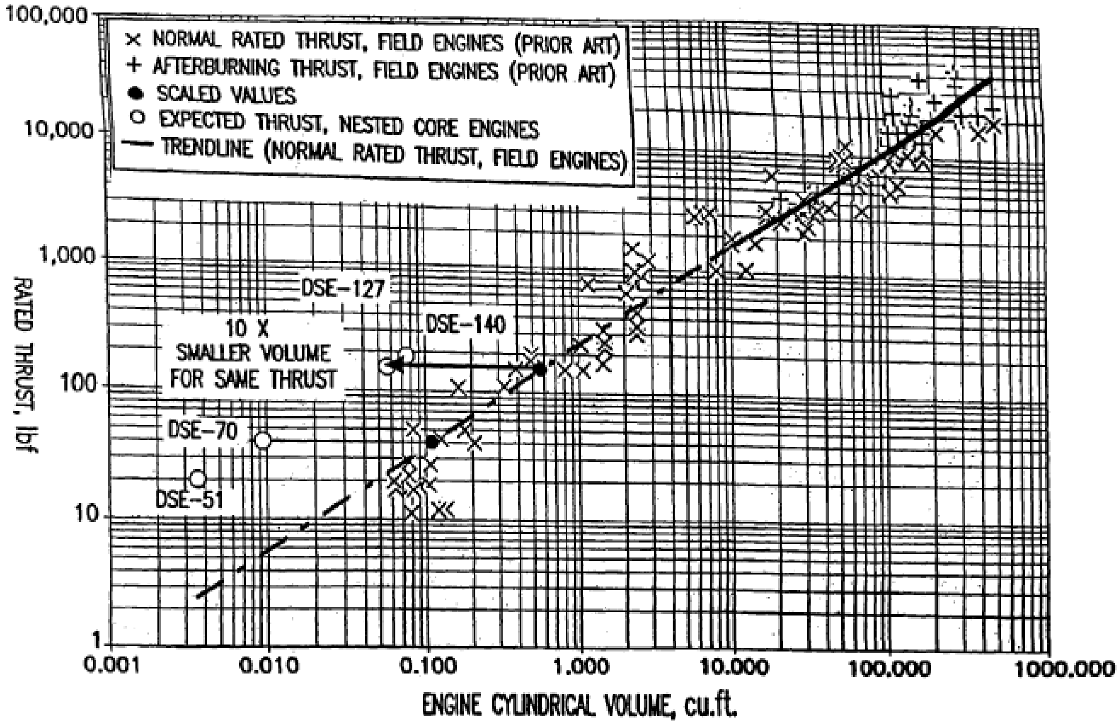


FIG.22

Dev's Figure 22, above, depicts rated thrust (lbf) compared with engine cylindrical volume (cu.ft.) illustrating that compared to conventional gas turbine engines, nested core engines are more efficient because they generate the same thrust at a smaller volume. As illustrated by the horizontal arrow in Figure 22 translating the efficiency data point along the volume axis, Dev describes that compared to conventional gas turbine engines, nested core gas turbine engines "offer[] very significant reductions in engine overall volume and weight." Ex. 1032, 18:25–26.

UTC is correct, on the one hand, that what is not shown or described in Dev is specifically the volume *of the turbine section* compared to thrust. PO Resp. 67. By itself, Dev does not explain or express that there is the same or similar efficiency correlation between varying the *turbine section* volume and thrust. On the other hand, it is clear from UTC's evidence in Figure 22 that "Dev discloses that thrust *to engine volume* was a known [result effective variable].” Reply 28; *see also Applied Materials*, 692 F.3d at 1297 (The Federal Circuit found that “prior art taught that the dimensions could be modified and that modification would affect pad performance, which was sufficient to find the dimensions to be **result-effective variables**.”). The specific question we must answer, here, is whether GE has provided sufficient persuasive evidence for us to determine that the claimed ratio, or result, i.e., the claimed “power density,” which uses “volume of the turbine section,” as opposed to the entire engine volume, would have been recognized in the art also as a result effective variable.

As discussed above, GE’s declarant, Dr. Attia, testifies that the claimed power density “is simply the ratio of thrust to turbine section volume, which was known in the art to be a result effective variable before the earliest priority date of the 751 Patent.” Ex. 1003 ¶ 72. Dr. Attia testifies that “[a] POSITA would readily understand that turbine volume is a subset of engine volume, and that Dev’s disclosure of the relationship between force to engine volume similarly indicates that the relationship between force to turbine volume is also a result effective variable.” *Id.* ¶ 75. Dr. Attia explains that the benefits of reducing the turbine volume were well known in the art and that a person of ordinary skill in the art understood that a geared turbofan engine provides better engine efficiencies by “decoupling the fan from the LPT and allowing the LPT to spin at a faster rate, meaning less LPT stages are needed to generate the same thrust.” *Id.* ¶ 84 (citing Ex. 1022, 4). For support Dr. Attia points to Jane’s Aero Engines, which explains that for a geared turbofan engine (“GTF”),

> [t]he low pressure turbine runs more than twice as fast than an ungeared engine, while the geared fan is about two-thirds slower. Turbine stages are shorter, spin faster and are lighter. (There are 1,500 less aerofoil sections in the GTF compared to the

> ungeared). The engine will be 10 percent shorter (turbine simplification).

Ex. 1023, 6. Jane's Aero Engines persuasively corroborates Dr. Attia's testimony that "prior art confirms that reducing the size of the LPT (as in a geared engine) for a constant level of thrust (*i.e.*, increasing its power density) was known to be result-effective because it affects the length, weight, and parts count of an engine." Ex. 1003 ¶¶ 85, 86, 87 (citing Ex. 1023, 6; Ex. 1033, 1:36–2:63; Ex. 1039, 14–17, 18, Fig. 11.6).

GE's argument that "power density" as a ratio of thrust to turbine volume would have been understood by a person of ordinary skill in the art as a result effective variable is compelling and supported by a preponderance of the evidence. Dr. Attia's testimony that a person of ordinary skill in the art would have recognized the ratio of engine thrust to turbine volume, as a proportional subset of the entire engine volume, to be a result effective variable is corroborated by the evidence in prior art references, for example, Jane's Aero Engines explaining the benefit of shorter turbine sections in GTF engines. *See Koninklijke Philips N.V. v. Google LLC*, No. 2019-1177, 2020 WL 485909, at *7 (Fed. Cir. Jan. 30, 2020) (Explaining the importance of corroborating expert testimony, the Federal Circuit stated that "[t]he Board supported its additional findings . . . with, for example, citations to an expert declaration as well as the Hua reference."). We are persuaded by Dr. Attia's testimony that a person of ordinary skill in the art would have recognized that reducing the volume of the turbine, indicated as beneficial by Jane's Aero Engines, necessarily reduces the volume of the entire engine. *See* Ex. 1003 ¶ 21 (Dr. Attia explains that "[t]urbofan engines are generally comprised of the following sections: an inlet section, a fan section, a compressor section, a combustor section, a turbine section, and an exhaust section.”).

Additional industry publications support Dr. Attia’s testimony. An article in INTERAVIA, June 1998, explains that compared to a direct drive engine, in a geared turbofan engine “[t]he LP turbine and compressor spin faster, which means that they can be made smaller in diameter, shorter and simpler: the engine has 52% fewer compressor and turbine blades than a conventional turbofan.” Ex. 1021, 2. An article titled “AERO-ENGINE DESIGN: FROM STATE OF THE ART TURBOFANS TOWARDS INNOVATIVE ARCHITECTURES,” published by the Von Karmann Institute for Fluid Dynamics, March 2008, compares LPT efficiency in a conventional direct drive turbofan engine to high-speed LPT’s in geared turbofan engines, and explains that in the geared turbofan engine “[t]he high rotor speed allows for a significantly reduced stage count of the turbine for a given work extraction . . . [t]he high speed LPT achieves high specific work output by means of high rotational speed per stage.” Ex. 1022, 17–19. Indeed the ’751 patent states, consistent with the prior art, that “reducing or eliminating the number of vanes in the low pressure turbine 46 shortens the axial length of the turbine section 28. Thus, the compactness of the gas turbine engine 20 is increased and a higher power density may be achieved.” Ex. 1001, 5:16–20. The ’751 patent provides no indication that reducing the length and thus the volume of the turbine section and hence the engine was in any way novel, new or unknown to those of ordinary skill in the art. *See id.*

Also, UTC does not point to persuasive evidence that rebuts GE’s position, for example, any testimony by Dr. Spakovszky that contradicts Dr. Attia’s testimony and supporting evidence. PO Resp. 67–68. We are not swayed by UTC’s argument that “power density” is not a result effective variable because Dev lacks an explicit reference to the claimed "volume of the turbine section." *See Applied Materials*, 692 F.3d at 1297 (The Federal Circuit has explained that "[g]enerally, a claim to a product does not become nonobvious simply because the patent specification provides a more comprehensive explication of the known relationships between the **variables** and the affected properties." (emphasis added)); *see also KSR*, 550 U.S. at 418 ("[T]he [obviousness] analysis need not seek out precise teachings directed to the specific subject matter of the challenged claim, for a court can take account of the inferences and creative steps that a person of ordinary skill in the art would employ.").

Additionally, we do not view the use of "turbine volume" as opposed to "engine volume" in a known engine efficiency concept as anything more than a basic mathematical relationship, i.e., a ratio of two known variables, and we do not find that determining this ratio requires more than ordinary skill. UTC's argument that the ratio using turbine volume as opposed to engine volume somehow exhibits improved performance in the claimed range, or a novel understanding over prior art efficiency concepts, does not reflect the correct standard for an obviousness analysis as it is well settled that improved performance, alone, is not sufficient. *See In re Huang*, 100 F.3d 135, 139 (Fed. Cir. 1996) ("[E]ven though applicant's modification results in great improvement and utility over the prior art, it may still not be patentable if the modification was within the capabilities of one skilled in the art.").

We are persuaded that "power density" recited in claim 1 as the ratio between thrust and turbine size would have been recognized in the art as a result effective variable that would have been desirable to optimize in order to improve engine efficiency. "A recognition in the prior art that a property is affected by the variable is sufficient to find the variable result-effective." *Applied Materials*, 692 F.3d at 1297. Dev recognizes that the values of engine volume and thrust affect the efficiency performance of an engine and, as we have explained above, a person of ordinary skill in the art understood that turbine volume is a proportionally related sub-part of engine volume. *See* Ex. 1032, 5:7–6:27.

UTC's reliance on *Schwarz* and the argument that Dev does not disclose explicitly thrust to turbine volume ratio fails to provide persuasive evidence that the range of 1.5 lbf/in^3 to 5.5 lbf/in^3 is an unexpected result. *See* PO Resp. 67–68. While it may be that this range is representative of a highly efficient gas turbine engine, UTC has not pointed to persuasive evidence showing that the summary of results, for example in Table 1 of the '751 patent, are unexpected. *See* Ex. 1001, 10:60–11:23 (The '751 patent states that "[e]ngines made with the disclosed architecture . . . provide very high efficient operation, and increased fuel efficiency and lightweight relative to their thrust capability.").

On the full record now before us, we are persuaded that GE has shown by a preponderance of the evidence the necessary reasoning and motivation supported by evidentiary underpinnings to show that claim 1 would have been obvious to a person of ordinary skill in the art in view of Knip.

h. Claim 2

Claim 2 depends directly from claim 1 and recites:

> The gas turbine engine as recited in claim 1, wherein the fan drive turbine has from three to six stages.

Ex. 1001, 13:34–35. According to GE, "Knip discloses a LPT (*i.e.*, fan drive turbine) with five stages." Pet. 44 (citing Ex. 1006, 11; Ex. 1003 ¶ 113). UTC does not provide any substantive rebuttal for dependent claim

2, relying apparently upon its arguments with respect to claim 1 as discussed above. *See generally* PO Resp. 1–68. Our review of Knip is consistent with GE's position. Knip's Table II discloses an LPT having five stages for both the baseline engine and the advanced engine. Ex. 1006, 11, Table II.

i. Claim 3

Claim 3 depends directly from claim 1 and recites:

> The gas turbine engine as recited in claim 2, wherein said number of fan blades is less than 18 and the second turbine has two stages.

Ex. 1001, 13:36–38. According to GE, Knip's Table II "reveals that the advanced engine contains a two stage HPT." Pet. 44–45 (citing Ex. 1006, 11, Table II; Ex. 1003 ¶ 115). GE admits that Knip does not disclose a number of fan blades "less than 18" as recited in claim 3. Pet. 45. GE argues that the number of fan blades is a result effective variable, and that it is well known in the art, for example from Decker (Ex. 1007), that "reducing the number of fan blades increases the efficiency of the engine." Pet. 45 (citing Ex. 1007 ¶ 46–47). UTC does not provide substantive rebuttal for dependent claim 3, relying apparently upon its arguments with respect to claim 1 as discussed above. *See generally* PO Resp. 1–68.

Dr. Attia provides unrebutted testimony that "the number of fan blades is a result effective variable, and a POSITA would have been aware of the advantages of reducing the fan blade count." Ex. 1003 ¶ 116. Dr. Attia explains persuasively that "turbofan engine designers utilize tip solidity as a design parameter for the fan of an aircraft turbofan engine because the design of the fan blade tip section is a limiting factor. Lower tip solidity is desirable, and reducing fan blade count is one way to achieve a lower tip solidity." *Id.* ¶ 88. Dr. Attia points out that Decker teaches "a substantial improvement in efficiency . . . may be obtained by decreasing tip solidity." *Id.* (citing Ex. 1007 ¶ 46). One way of decreasing tip solidity according to Decker is "by decreasing the number of fan blades." Ex. 1007 ¶ 47. Dr. Attia testifies also that it well known to those of ordinary skill in the art that "fewer fan blades means a lighter and more efficient engine." Ex. 1003 ¶ 89 (citing Ex. 1015, 1:19–33, 1:49–57).

Dr. Attia's testimony is persuasively supported by the prior art references to Decker (Ex. 1007) and Murphy (Ex. 1015). Decker for example states that instead of reducing the chord to diameter C/D ratio to decrease blade solidity, "the chord to diameter C/D ratio may remain constant or equal between the turbofan designs, with instead the number of fan blades being reduced to twenty or eighteen in the preferred embodiments." Ex. 1007 ¶ 49. Without evidence to the contrary, we credit Dr. Attia's testimony that is consistent with our review of the prior art and the '751 patent itself. One of ordinary skill in the art would have known from Murphy and Decker that lowering the number of fan blades can be a benefit to efficiency. *See e.g.*, Ex. 1007 ¶ 75 ("[R]educing tip solidity by reducing blade count instead of the chord to diameter C/D ratio permits a further improvement of turbofan efficiency."). Consistent with Decker and Murphy, the '751 patent discusses general power transfer efficiency improvements by reducing the number of fan blades. Ex. 1001, 6:2–7. Given the level of ordinary skill and knowledge in the art, that lowering the fan blade count increases efficiency, we determine that blade count is a result effective variable because it is well known to effect the efficiency of the engine. What we do not find in the '751 patent Specification or in any of UTC's substantive arguments is evidence of unexpected results arising from decreasing the fan blade count to less than 18. *See* Ex. 1001, 5:59–62 (The

’751 patent states that the “example gas turbine engine includes the fan 42 that comprises in one non-limiting embodiment less than about 26 fan blades. In another non-limiting embodiment, the fan section 22 includes less than about 18 fan blades.”). On the whole, the evidence of record does not support a finding that the claimed invention produced unexpected results.

j. Conclusions as to obviousness for claims 1, 2, and 3

Having considered each of the pertinent *Graham* factors individually, we now weigh them collectively. The level of ordinary skill in the art along with the scope and content of the prior art, as well as the differences between the prior art and claim 1, weigh in favor of GE’s contention that claim 1 would have been obvious. True, Knip does not specifically disclose the element of “power density” as it is defined in the claim as a ratio of SLTO thrust to turbine section volume, nor the specific range of power density between 1.5 to 5.5 lbf/in^3. GE has shown persuasively that a person of ordinary skill in the art understood the concept and efficiency characteristics of engine volume compared to thrust as shown by Dev, and that varying the turbine volume, as a subset of engine volume, is known to be one way of varying engine volume. As discussed in Section III.B.2.e.–f., we credit Dr. Attia’s analyses of Knip’s advanced engine, which showed persuasively that one of ordinary skill in the art would have used the engine cycle and turbine volume measurement parameters expressly provided in Knip, along with certain reasonable assumptions and estimates as to missing parameters, and obtained SLTO thrusts resulting in values within the claimed range as set forth in claim 1.

UTC presented no objective indicia of non-obviousness in favor of non-obviousness.

In addition, as set forth in Section III.B.2., we are persuaded that despite advocating the use of advanced materials for designing gas turbine engines that had yet to be built, Knip is sufficiently enabled with respect to the claimed invention so that a person of ordinary skill in the art would have determined a power density as defined in claim 1, and within the range proscribed in claim 1. In Section III.B.3.g., we determined that "power density" is a result effective variable that a person of ordinary skill in the art would have optimized and that UTC has not provided probative evidence that the claimed range was an unexpected result.

In Sections III.B.3.h–i, dependent claim 2 recites a limitation disclosed by Knip, and claim 3 recites a limitation, i.e., "number of fan blades less than 18," which we determine is a result effective variable because reducing the number of fan blades has been shown to be something that a person of ordinary skill in the art would try to optimize to increase efficiency.

On the whole, we determine that the first three *Graham* factors weigh in favor of obviousness. We find that GE has demonstrated, by a preponderance of the evidence, that a person having ordinary skill in the art would have been motivated in the interests of increasing engine efficiency to consider the teachings in Knip, including performing an engine cycle and volume analysis of Knip's advanced engine to determine the engine's overall efficiency including the concept of "power density." GE provides the requisite reasoning, supported by rational underpinnings, for performing its analysis of Knip based on the level of ordinary skill in the art. *See KSR*, 550 U.S. at 418 (citing *In re Kahn*, 441 F.3d 977, 988 (Fed. Cir. 2006)) ("[O]bviousness grounds cannot be sustained by mere conclusory statements; instead, there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness.”). Accordingly, we conclude that GE has demonstrated by a preponderance of the evidence that claims 1, 2, and 3 would have been obvious in view of Knip.

4. Analysis – Claims 15 and 16

Independent claim 15 and dependent claim 16 are word for word, identical to claims 1 and 3, except that claim 15 includes the additional limitation of the speed change system “having a gear reduction.” Ex. 1001, 14:56–57. Our review of Knip is consistent with GE’s position that “Knip discloses a gearbox that connects the low pressure turbine to the fan.” Pet. 48 (citing Ex. 1006, 6; Ex. 1003 ¶ 118). Knip does not explicitly state that the “gearbox” between the fan and LPT is a reduction gear. *See* Ex. 1006, 2 (Knip describes that the advanced engine has “a geared fan.”). Dr. Attia however testifies that a person of ordinary skill in the art would have understood that engine efficiencies of Knip’s geared turbofan engine, and in fact any geared turbofan engine, were increased by use of a gear reduction because “[t]hese efficiencies are the product of decoupling the fan from the LPT and allowing the LPT to spin at a faster rate, meaning less LPT stages are needed to generate the same thrust.” Ex. 1003 ¶ 84 (citing Ex. 1022, 4). UTC provides no evidence or argument contradicting Dr. Attia’s testimony.

We are persuaded that a person of ordinary skill in the art would have understood Knip’s geared turbofan engine to include “a gear reduction” as recited in claim 15. We are persuaded for the same reasons as discussed above with respect to claim 1 that the remaining limitations, including “power density” as recited in claim 15, would have been obvious in view of Knip. Similarly, we determine with respect to claim 16, like claim 3, that a person of ordinary skill in the art would have been aware that lowering the fan blade count can provide increased engine efficiency and optimizing a blade count to be lower than 18 would have been obvious to one of ordinary skill in the art.

Accordingly, for the same and similar reasons as discussed above relative to claims 1 and 3, we conclude that GE has demonstrated by a preponderance of the evidence that claims 15 and 16 are unpatentable over Knip.

C. Claims 3 and 16— Alleged obviousness over Knip and Decker

Because we determine that claims 3 and 16 are obvious in view of Knip, we need not reach the challenge of claims 3 and 16 as obvious over Knip and Decker. *See SAS Inst. Inc. v. Iancu*, 138 S. Ct. 1348, 1359 (2018) (holding a petitioner "is entitled to a final written decision addressing all of the claims it has challenged").

IV. SUMMARY

Petitioner has proved by a preponderance of the evidence that claims 3 and 16, as they depend from disclaimed independent claims 1 and 15 respectively, would have been obvious over Knip.[12]

We do not reach the ground considering whether claims 3 and 16 are unpatentable over Knip and Decker.

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[12] Should Patent Owner wish to pursue amendment of the challenged claims in a reissue or reexamination proceeding subsequent to the issuance of this decision, we draw Patent Owner's attention to the April 2019 *Notice Regarding Options for Amendments by Patent Owner Through Reissue or Reexamination During a Pending AIA Trial Proceeding*. *See* 84 Fed. Reg. 16,654 (Apr. 22, 2019). If Patent Owner chooses to file a reissue application or a request for reexamination of the challenged patent, we remind Patent Owner of its continuing obligation to notify the Board of any such related matters in updated mandatory notices. *See* 37 C.F.R. § 42.8(a)(3), (b)(2).

In summary:

Claims	35 U.S.C. §	Reference(s)/Basis	Claims Shown Unpatentable	Claims Not shown Unpatentable
3, 16	103	Knip	3, 16	
3, 16	103	Knip and Decker		
Overall Outcome			3, 16	

V. ORDER

For the reasons given, it is

ORDERED, based on a preponderance of the evidence that claims 3 and 16 are unpatentable; and

FURTHER ORDERED that, because this is a Final Written Decision, any party to the proceeding seeking judicial review of this Decision must comply with the notice and service requirements of 37 C.F.R. § 90.2.

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