July 24, 2007

To: **Federal Aviation Administration,**
Transport Airplane Directorate
Attention: Rules Docket (ANM-113),
Docket No. NM368,
1601 Lind Avenue SW
Renton, Washington 98057-3356

From: **Vincent A. Weldon**
46 year Boeing employee, now retired

Subject: **Response to invited comments on Docket No. NM368, Special Conditions No. 25-07-05-SC: Boeing Model 787-8 Airplane; Crashworthiness**

To whom it may concem, within the the FAA Transport Airplane Directorate:

Federal Register / Vol. 72, No. 111 / Monday, June 11, 2007 / Proposed Rules, page 32021, states that the FAA invites interested persons to participate in this rule making by submitting written comments, data, or views, on or before July 26, 2007. This disclosure is hereby hand-delivered to the The Transport Airplane Directorate, in duplicate (as required), on July 24, 2007, 2 days prior to this deadline. Please send me the enclosed addressed and stamped postcard, marked with the subject docket number, indicating timely receipt of this disclosure, to my address noted at the end of this disclosure.

It is my understanding that the FAA is chartered by Congress to accomplish two primary responsibilities. The first is to enforce aviation safety, particularly during the development of a new jetliner. The second is to promote aviation and the industry, particularly in helping in the introduction of new technologies. When a new jetliner is introduced into the commercial market, particularly one that involves new technologies, the manufacturer and the FAA must proceed with caution to assure that the jetliner does not compromise the existing level of safety afforded the public. The Boeing Company's announced technology philosophy, which unambiguously commits Boeing to this integrity, is as follows:

> Boeing has been building safe airplanes since 1916. The Boeing technology philosophy is a time-proven design guideline that helps insure the safety of all Boeing commercial airplanes. **Boeing will not use new technologies, or the capabilities they make possible, unless they provide distinct safety, operational or efficiency advantages and do not compromise existing safety. Advantages that fail this simple test simply do not fly on Boeing jetliners. Why? Because the ill-considered application of new technologies can lead to unintended consequences that compromise the safety already achieved.**

[Emphasis added.] This decades-proven and publicly accessible technology philosophy clearly defines the criteria which must be met before transitioning any new technology to a Boeing commercial jetliner. Significantly neglecting this commitment, regarding an important safety issue, is tantamount, to betraying the public's trust of Boeing and the FAA. As I will discuss in further detail, the potential risk to the flying public mandates that the technologies utilized in the 787 are carefully evaluated before they are implemented.

While it is true that composite structures do have far superior fatigue and corrosion resistance characteristics, these advantages are more than balanced in the undesired direction by the far fewer failure modes of aluminum than for composite structures. This characteristic especially complicates the analysis of composites, about which there is far less proven knowledge than for aluminum structure. Further, there is a very low linear strain to failure load/strain characteristic for the type of relatively brittle composite structure used for the 787.

For aluminum, by comparison, this ductile material yields before failure at strains of up to about 10%, which provides excellent shock-absorption capability as well as compatibility of interface deformations to assist low cost final assembly. In addition, composite structures are anisotropic. That is, they have properties that vary with the direction of fibers in the structure, which weakens their transverse properties and complicates their analysis. This is especially of concern because of the much greater variations in mechanical properties for composites, compared to aluminum, mostly in compression (due to the formation of voids and delaminations that cause failure in compression) and in the transverse direction.

By comparison, aluminum, being isotropic (same properties in all directions), has none of these concerns. Also, the less mature composite structure data base, compared to that of aluminum, is of concern, especially regarding sustained quality relative to specification requirements. With the suppliers now responsible for detail design, and not just for manufacturing to Boeing specifications, significant quality variations can be expected from the various suppliers as they try to hold down costs. This degree of passing detail design responsibility to suppliers has never before been allowed by Boeing, for commercial jetliners, which help enabled their past success.

These are just a few issues to illustrate the problematic situation, before I get to the heart of the safety issues. Not thoroughly thinking-through all the risk ramifications in the rush to redefine how a jetliner is designed, with emphasis on its fuselage has led to serious safety concerns. For the 787's fuselage, choosing to proceed with an unproven composite one which must protect up to 300 human beings, <u>without first thoroughly testing a prototype</u>, while at the same time significantly shortening the development schedule, has been to me, grossly inconsistent with the company of great integrity that I joined in 1960.

James McNerney as the new Boeing leader in mid 2005, stated shortly before this selection, as reported in the June 15, 2005 issue of the Seattle Post-Intelligencer, that leading the embedding of instinctive ethical behavior into the Boeing culture would be one of the top priorities of the new Boeing leader. Unless ethical behavior is instinctive, which means that skirting the ethical boundaries is habitually discouraged, it will try to get away with many deceitful practices for the sake of short-term gain. Worse, with the signal that this is acceptable, the persons within the organization having the most integrity, will realize that fighting this system is counter-productive to their career advancement, so they also begin to enable, just by keeping quiet. I have seen it at work. It is insideous. Eventually the best people are ousted or simply leave in order to, so to speak, save their own souls.

In publicly speaking, from his heart, the real truth recorded above (for which I heard managers strongly criticize him and deny that change was needed), Mr. Platt clearly recognized that something was amiss within Boeing's soul—which is the core reason why the current, well covered-up, situation covered in this disclosure has happened. One of my purposes in sending this disclosure to you is to solicit your help in helping Boeing to recover its former soul, that made it so great, because you are the FAA, the governmental agency which the public trusts to protect them-- which means to at least the level of safety already achieved, for all aspects of commercial jetliner operation. This is only what the above Boeing technology demands. If you refuse to do this, you will show that the FAA also no longer has its former soul of greatness, and needs to be significantly changed.

Continuing now with a summary of the characteristics of the type of composite structure used in the 787, when compared to aluminum, composites are more sensitive to hot/wet and freeze/thaw conditions and through-thickness crack growth. These represent fatigue-like failure modes which composite structures are advertised to not have, which turns out to be false—the fatigue is just of other types, all of which are relatively poorly understood. Also, composites can be subject to delamination, while aluminum is not subject to this failure mode at all, and the initial as well as in-service flaw/damage size of composites is not well-defined compared to these for aluminum.

In addition, the historical record shows that jetliner composite structures are "more prone to impact damage, the economic repair of which has typically been limited to minor damage," from R. Whitford, "Evolution Of The Jetliner," The Crowood Press, copyright 2007). The damage from impact is often beneath the surface micro-cracking, which is very hard to visually identify. For that reason, extra material thickness is provided at weight penalty, to implement the dubious strategy: If it can't be seen from 5 feet away, under "normal" lighting conditions, you don't have to do anything about it. By comparison, aluminum requires no such obviously risk-prone, relatively subjective strategy. Dents in aluminum are easily visually detected and repaired using proven low-cost techniques. Often the aluminum is stronger after being dented, due to cold-working, and nothing needs to be done to fix the dent.

Further, the kind of composite structure used for the 787 is combustible, and burns furiously in a fuel-fed fire, liberating highly toxic smoke and tiny inhalable carbon slivers. The all-composite airframe aircraft in which the baseball star, Cory Lidle died, in 2006, along with his flight instructor, after it impacted a high-rise apartment building (the engine was thrown into an apartment), burned to the point where virtually no structure was left except some small pieces of metal. Aluminum does not burn at fuel fire temperatures, but merely melts, after reflecting and conducting away much heat, in a survivable crash, helping to allow passengers to escape from the aircraft. This benefit is often available even though the aircraft is engulfed in fire, partly because aluminum does not liberate flames, smoke or inhalable slivers. Also, for a large all-composite airframe commercial jetliner, these products of combustion will be able to cause an environmental impact well beyond any that ever before resulted from the major crash of an aluminum jetliner.

Another concern with the use of composite structures rests with the way the lightning strike protection issue is being addressed on the 787. Lightning strikes occur, on average, about two times per year on each commercial jetliner. For the 787's current lightning protection system I do not have even close to the same level of confidence that I have for this inherent protection capability which is inherent on aluminum commercial jetliners. This doubt is based on a combination of important factors, including compromises presumably made due to the advertised desire for quick final assembly (3 days, eventually). I believe that this priority has influenced the adoption of a far less direct current dispersion design compared to what inherently exists for current aluminum jetliners. This is because the decision has apparently been made that it would take too long, during final assembly to provide screen-to-screen continuous lightning current transfer capability along the interface between adjacent airplane major segments. This approach would approximate the skin-to-skin continuous current transfer capability inherent in aluminum structure airplanes, but it is not being used.

To understand what has been implemented on the 787, for lightning protection, it is necessary to know that the composite structure of the 787 is basically non-conductive due to the epoxy matrix in which the semi-conductive carbon fibers are embedded. This matrix is bonded to the carbon fibers and acts as an insulator. If it were not for the conductive screen bonded to the surface ply there would be no ability to disperse the lightning current. This screen is non-structural and causes a weight penalty for, the composite structure. There is no corresponding weight penalty for aluminum structure because it is inherently very electrically conductive. But, on the 787, to minimize the weight penalty, the composite structure conductive screen is made as light weight as feasible to still perform its conductive function in the event of a lightning strike.

The resulting composite structure protection system is comparable to a complex and fragile "band-aid" stuck onto a structure which is vulnerable to, for example, hail damage. But the screen is not structural, and therefore gets less respect – sort of like "out of sight, out of mind." However, an aluminum structure is much more robust for dispersing lightning current. It can disperse a lot more current than it will ever see, while the composite structure screen, has far less margin to withstand lightning current, in order to save weight. So, by definition, the screen causes a compromise of the lightning strike current dispersion safety already available on current jetliners. In order to achieve adequate conductive continuity between adjacent major structural fuselage segments, the lightning current in the screen of one segment must transition to the screen of the adjacent segment through the primary structure bolts which attach these segments. If these bolts do not fit tightly enough in the structural holes through which they are installed, there will be current-arcing causing invisible structural flaws in highly loaded areas. Over time, these flaws in the bolts could cause structural failure of a fuselage joint. Detection of a growing flaw in the bolt is an inspection challenge that an aluminum jetliner does not have to cope with.

An additional type of "band-aid" that has been implemented in order to, hopefully, make the 787 as safe as that of an aluminum jetliner, is the nitrogen inerting system to help prevent explosion of fuel vapor above the liquid level within the wing and fuselage fuel tankage. A current aluminum jetliner does not need this system to meet the required level of safety from this catastrophic (in flight) event. Yet, Boeing has said that it will still be able to fly even if this system is not operable (even though a group of specialists within Boeing recommended against this). The required safety level for protection against a fuel tank explosion is that there be no more than a one in one billion chance of having such an event. To demonstrate that this safety goal has been met will take years of testing due to the sample size which must be accomplished to verify such a challenging goal.

The less than one in one billion chance, of not having a fuel tank explosion, has already been demonstrated, for aluminum jetliners, over decades of proven safe operations. But, in an attempt to help justify that the 787's lightning protection system, will not allow such an event, the B-2 bomber, which uses a conductive screens and has fuel tank vapor inerting, is sometimes cited as a proof that a large composite aircraft has adequate lightning strike protection. This comparison is not appropriate partly because there are only about 20 B-2s in the entire Air Force inventory and they hardly ever fly compared to the challenging flight schedule for a commercial jetliner. Further, the B-2 doesn't have to be as safe as a jetliner because it has only two occupants, each having an ejection seat. Also, it generally flies around thunderstorms, a luxury not often available to commercial jet operations which often require flying directly through bad weather in order to arrive at a pre-planned airport on schedule. With all these lightning protection novel features, with respect to commercial jetliner operations, it is troubling that the FAA has not proposed special conditions for the 787 lightning strike system.

With the issuance of crashworthiness special conditions less than 10 months from the currently scheduled first 787 delivery, it is clear that the program started with an unacceptable knowledge base regarding the use of a composite fuselage. The subject crashworthiness special conditions states that, "because of the novel design features features of the 787, the FAA intends to require Boeing to conduct an assessment to ensure that the 787 will not have dynamic characteristics that differ significantly from those found in previous certifications." The crashworthiness special conditions also state that Boeing must study the effects of a range of impact velocities up to 30 feet per second. The 30 feet per second impact velocity is the impact level for existing crashworthiness established by FAA drop testing of a 737 fuselage segment in 2000. Since 30 feet per second is the proven approximate crash-landing vertical velocity impact limit, for general passenger survivability, inherent in existing commercial jetliners, including the 737, 757, 767, and 777, this brings into question the FAA's motives in testing a range of impact velocities below 30 feet per second crashworthiness safety already achieved, if the FAA really wants the 787 to uphold existing safety?

It is important to realize that a complex set of interacting dynamic characteristics determine the crash-landing shock loads transmitted to the passengers during a crash-landing. The only comprehensively documented drop test results for an existing large commercial jetliner, to quantify these characteristics , was the very thorough FAA drop test (including instrumented and seated anthropomorphic crash-dummies as well as loaded baggage bins, etc.) of a 737 aluminum fuselage segment. This is the current documented standard for existing crashworthiness which the 787 must at least match. For this test, the fuselage segment drop from a height of 14 feet produced a 30 foot per second impact velocity onto concrete. The average g-level transmitted to the seat tracks was about 20 g's, vertically (spine direction), the same g-level considered by NASA to be the upper average survivability limit for occupants when used as the earth-landing design limit for Apollo Astronauts returning from a lunar mission.

This drop test, for which publicly accessible results are available, caused the lower frame of the 737 fuselage barrel section to be flattened by about 1.5 feet of crushing, under an almost constant load. This enabled enough gradual deceleration, of the seated anthropomorphic crash dummies, to make the event survivable, on an average g-level human passenger exposure basis. The aluminum shell, although crumpled, still stayed intact and would likely have been an effective fire barrier long enough to let the occupants escape. This same amount of required distortion to decelerate the passengers, applied to a composite structure having composite frames , would easily result in an induced level of strain of the relatively brittle composite fuselage frames of the 787 to instantly cause a large lower fuselage shatter-hole, through which fire and toxic

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smoke could immediately penetrate. This is certainly not the upholding of existing safety, yet Boeing claimed publicly, in 2006, that a step backward in safety can never be taken in the development of a new jetliner.

In order to obtain a valid comparison with this existing safety test, a 787 fuselage, outfitted as noted above for the 737 fuselage, must be dropped from the same 14 foot height that the 737 was dropped from, and onto concrete. I stated this to the 787 Director of Structures Integration, in late December, 2005. However, he strongly objected to such a thorough test, complaining about what it might show. Being a structures expert, he was well aware that composite structure of the type being used for the 787 airframe, is very brittle compared to aluminum and that prior computer simulations show them to cause unsurvivable g-level loadings on the passengers.

Despite knowing this, he stated to me that he wanted to proceed with a range of impact velocities using lower cost half-round fuselage segments with no instrumented crash dummies. This would obviously not be able to include loaded bins, as were included in the 737 drop test, which is another reason why a full barrel section is required for the 787 drop test. All or these simplifications in testing are obfuscations desired to to avoid a direct comparison with the FAA's 737 existing safety crashworthiness drop test, and also, possibly, so that a film record will not be created of what actually happened to the structure (an analysis result would be much easier to deny access to, on proprietary data grounds). I am concerned that the FAA's recently issued crashworthiness proposed special conditions may be consistent with what this person wanted, which would indicate no real change in what appears to be a very cozy Boeing / FAA relationship that I believe Congress needs to look into. Is this also at least partly implied by the recent statement of Congressman Jerry Costello, Chairman of the House Aviation Sub-Committee? He stated:

"We intend to provide what has been lacking in the past: aggressive oversight of the FAA and other programs under our jurisdiction...The number one goal of our government is safety and security."

The emergency status of the safety concerns in this disclosure is highlighted by the fact that the previously mentioned smoke from burning carbon-epoxy composite structure, of the type used by the 787, is so toxic that it is no longer allowed in the interior of a jetliner, by the FAA. In spite of this, the FAA does not seem to mind that this combustible material comprises most of the airframe's primary structure. This composite structure-caused toxic smoke could not only immediately enter into a crash-landing caused lower fuselage shatter-hole, but also it would likely seriously incapacitate or kill passengers trying to escape from the crash-landing / fire through doors and as they try to use the inflated slides.

Overall, it is easy to see that what has been allowed in the rush to extreme innovation is a new world of fuselage materials and construction technologies that should have been well understood through extensive testing, under oversight of the the FAA, before ever being allowed to be the fuselage primary structure material. Compared to the proven aluminum structure knowledge base, Boeing has, as partly proven due to the need for to FAA to propose special conditions, only defined a significantly smaller percentage of what would comprise a data base of equivalent maturity to that which exists for aluminum, including for crashworthiness. At least in this latter area, the strategy seems to be: if you can't stand the answer, don't ask the question. In enabling this, the FAA's responsibility to enforce the upholding of existing crashworthiness safety appears to be of relative low priority compared to promoting industry interests.

Hopefully, the FAA will now decide to do the right thing, which is to enforce that existing passenger survivability be proven by demonstration that a segment of the 787's actual fuselage will provide the same level of crashworthiness safety that the 737 was proven to afford. This level is an average induced spine load of no more than 20g's, due to a 30 foot per second impact velocity onto concrete. Subsequently, the same impact-damaged fuselage segment would have to demonstrate that it could not be penetrated in less than 5 minutes (to allow sufficient time for rapid passenger escape from a fuselage sitting in a pool of burning fuel and composite structure.

The FAA should perform this testing, as shown by the following steps, as soon as possible, in order to support the 787 certification:

1) The FAA is responsible for providing attachment g-load factor requirements for the support of filled overhead storage bins so that the do not break loose and harm passengers in the event of a severe crash-landing which would be, on an average g-level basis, barely generally survivable in a current jetliner.

2) The year 2000 FAA sponsored and well-documented drop test of the comprehensively outfitted 737 fuselage barrel segment included determining the attachment g-load factors for overhead filled storage bins due to a crash-landing that impacted at a 30 feet per second impact vertical velocity. The average g-level experienced by the seated anthropomorphic dummies was, in fact, barely survivable (about 20 g's). The corresponding filled overhead storage bin attachment g-load factors were therefore very appropriate and useful for designing an aluminum jetliner fuselage, but not a composite one. Due to the relative brittleness of composite material compared to aluminum, the type of composite structure used for the 787 will cause much less shock-absorption capability, resulting in significantly higher overhead bin attachment g-loads at the same 30 feet per second impact velocity onto concrete. This test also provided the data needed to develop and calibrate computer simulation analysis tools for crashworthiness design of aluminum structure jetliners, but not for composite structure ones.

3) Unfortunately, the same thorough and orderly progression of effort has yet to be accomplished for composite structure jetliners. For example, as noted earlier, the simplified drop testing that Boeing has been conducting involves only a half (lower)-barrel segment, so that it is impossible to include the overhead storage bins. I shudder to think of what attachment g-load factors are being used to design the bin attachments, especially at a time when Boeing is trying to reduce the 787's overweight condition. The above process needs to be repeated for the composite 787, using a fully outfitted full circumference barrel segment. This would include seated and instrumented anthropomorphic dummies as well as filled overhead storage bins attached to the barrel segment. Compared to the weights that were carried atop the passenger and cargo floors, and within the overhead storage bins, the 787 drop test must use heavier weights in these areas, at levels that would be maximums in the 787.

4) At this late date, the main object is to demonstrate that what has been manufactured will not subject the passengers to greater risk than defined as existing safety by the above described previous 737 testing. If the drop test shows that the average g-level that the passengers experience is no greater than 20 g's, significant damage to the lower fuselage caused by the drop test must be subjected to fire and smoke penetration testing, not only to determine how fast the penetration increases as the composite structure itself burns, especially at the edges of any shatter-hole, therefore making it increasingly larger. The fire should be mainly fueled by jet fuel, in the presence of which, the composite structure used for the 787 airframe is known to burn furiously, liberating toxic smoke. This potential effect on passengers trying to escape from a burning jetliner that has crash-landed, must be assessed. If the fuselage drop test shows that the average g-level, to which the passengers are subjected is greater than 20 g's, the fuselage design must be modified and another barrel test conducted. Subsequent failures will result in further modifications until existing cash shock-absorption safety is proven, after which the above described fire penetration test must be passed, for the certification process to proceed. Any shortfalls in the general cabin passenger survival likelihood and ability to safely escape from the airplane after a crash-landing, of the existing safety described above, must be demonstrated before it is certified. All I am asking for is what Boeing has admitted is very important . For example, in their publicly accessible Flight Safety website, we read:

"In many of the accidents that have occurred, the airframe has remained largely intact following impact with the ground. Much of the destruction has occurred as a result of post-crash fire, which is why a speedy evacuation of an airplane that's gone down is so important."

safety level at least approaching the existing crashworthiness of the year 2000 FAA sponsored drop test of a 737 fuselage segment discussed above, was clearly demonstrated by the Airbus A340-300 which crash-landed at Toronto's Pearson International Airport on August 2, 2005. After over-running the landing, the jetliner ended up with its nose at the bottom of an approximately 30 foot deep ravine, and its tail slightly below the ravine's edge. The plane immediately burst into flames, yet all 309 occupants were able to escape from it within two minutes.

Another relevant and recent example is that, on March 6, 2007, a Garuda Airlines Boeing 737-400, with 140 occupants, crash-landed at Yogyakarta Airport in Indonesia. Like the A340 incident, the 737 over-ran the runway onto rough ground (in this case a rice-field rather than a ravine), breaking into separate segments and immediately bursting into flames About two thirds of its occupants are reported to have escaped from the wreckage even though the jetliner reportedly touched-down at about twice its normal landing speed.

These incidents illustrate that aircraft technology has reached the stage where challenging crash-landings, such as in the Toronto and Indonesia events, can be survivable due to the existing crashworthiness safety of these aircraft. Boeing and the other manufacturers of aluminum aircraft have demonstrated crash-landing survivability of current jetliners due to the continuous upholding of existing safety. The uninformed, but trusting, flying public naturally expects that the FAA is going to insist on at least the same crashworthiness that all 737 size and larger aluminum jetliner fuselages inherently provide.

In an effort to not be required by the FAA to change the 787 fuselage frame design, it is anticipated that Boeing will promote that engines under the wing smashing into the ground, wings ripping off, etc, should be counted towards absorbing crash-landing shock. This not acceptable because the 737 drop test didn't need such so-called assistance to provide passenger survivability at a 30 feet per second vertical impact onto concrete. Rationalize that these unpredictable energy-absorbing events should be counted-on, to help make the jetliner adequately crashworthy, is therefore certainly not upholding the safety already achieved, because if these events were accounted for on the 737, it would be able to be passenger survivable at a much higher than 30 feet per second impact velocity. So, if these events are used for the 787, it would have to provide passenger survivability at the same higher impact velocity, for the sake of providing equivalent crashworthiness. Also, the cost and schedule for doing a drop test that would include these events would be prohibitive.

It has been stated within Boeing, the FAA and even OSHA that the level of crashworthiness safety of the 787 composite fuselage jetliner can be considered to be equivalent to an aluminum fuselage one because it meets the same requirements. This premise is false because all previous jetliners have not been required to meet a specific requirement for the most fundamental crashworthiness safety factor, namely, the ability of its fuselage to absorb vertical impact shock loading. Presumably, this gap in requirements was justified because this capability always has been inherent for a ductile aluminum fuselage jetliner, have excellent plastic deformation capability. However, due to lack of this toughness, this certainly is not for the case for the type of relatively brittle composite structure being used for the new 787 jetliner. So, what is necessary for the crashworthiness special conditions demonstration requirements, is that the 787 can meet the same level of vertical impact shock-absorption crashworthiness demonstrated by the best-documented test for this capability by an actual aluminum jetliner fuselage. This is the year 2000 FAA sponsored 737 fuselage segment drop test discussed previously. The 787 version of this test, also discussed previously, must also demonstrate that the resulting fuselage damage will not allow immediate fire and toxic smoke entry into the fuselage, or hamper passenger escape through the doors and down the slides.

Finally, there is the issue of the relevance of non-uniform g-levels. For example, the 737 existing crash-landing shock-absorption safety drop test, discussed previously, resulted in an average passenger g-level spine exposure of about 20 g's when dropped from a height of 14 feet, which produced an impact velocity, onto concrete, of about 30 feet per second. Also, no significant rupture of the lower fuselage was produced, although the crush vertical depth for the lower fuselage was about 1.5 feet, indicating severe distortion. The fact that the passenger g-levels were not uniform across the fuselage is irrelevant because what is important is the average g-level that the passengers would experience, because the g-level per passenger is always variable due to many reasons, as a result of a survivable crash-landing. The same g-level variability occurs for the overhead storage bins. In both cases, the only practical goal is the AVERAGE g-level, and to claim otherwise is clearly unreasonable and indicative of an agenda which seeks to avoid the upholding of existing safety on the false premise that it has not been adequately quantified.

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