“My God It’s Full Of Holes”

1/08/2024

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Every aircraft has a number of holes in its fuselage. The function of these holes is usually pretty obvious. They are where wires need to pass through on their way from inside to the outside (landing lights, navigation lights, antenna wires, etc.). They carry the control cables from the pilots controls to the control surfaces they command. They make it possible to attach things like the wings to the fuselage, etc.

They accommodate windows through which the passengers can watch the World go by as they travel.

And the holes are also the mechanism that allows people to get into and out of an aircraft. In that role we call them "Doors."

Now holes in pressurized vessels have always been a problem for engineers. Holes are always points of weakness and when there is a lot of pressure either outside the vessel (like a submarine) or inside the vessel (like an airplane), you have to spend a lot of time as an engineer making sure your holes don't open when you don't want them to and, equally important, that they do open when you need them to.

It's not an easy task. Nor is it one where you want to cut corners or conduct any "value engineering." These are among the hardest tasks in engineering and should be given only to those with a vast experience and past success. More importantly, perhaps, vast experience and a history of learning what doesn't work from failure.

Any door in a pressurized aircraft fuselage is under tremendous stress and force in flight. A typical cabin differential is eight pounds of force per square inch. What that means is that, in flight, there is eight pounds of force pressing on every square inch of surface, including the doors, trying to blow them out.

The biggest doors in an aircraft are designated "Type A" doors. This is the kind of door that most of us are familiar with as it's the kind of door we pass through when getting on or off a flight to go visit our grandmother in San Francisco.

A Type A door is at least 42 inches wide by 72 inches tall. That's more than three and a half feet wide and six feet tall. A door that size has an area of 3,024 square inches. At eight pounds per square inch, or 3,024 x 8, we get a total force on the door of nearly twenty-five thousand pounds.

Get that? During ordinary flight each door has to withstand the same load generated on it by cabin pressure as if it was trying to hold back a rocket powered by a Space-X Kestrel engine.

Hold that, powered by FOUR Space-X Kestrel engines (each capable of 6,000 pounds of force)
(Image courtesy of WikiPedia)

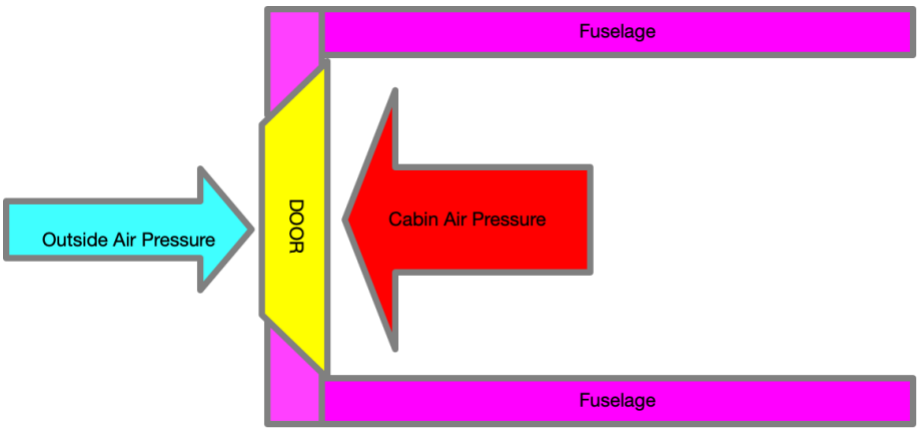
So why aren't doors being blown off of commercial airplanes *all the time?*

Simple, engineering.

Cabin doors are designed to fit into the holes in the fuselage like a wine cork fits into a wine bottle. The doors themselves are larger than the holes they cover. What's more they have a wedge shape to them that causes them to seal in the hole more tightly the greater the pressure difference between the outside and the inside.

It's an elegant solution that ensures that the door cannot be opened in flight. It relies on no complex mechanism other than air pressure to keep it safely closed. On the ground, where there is no difference in air pressure between the outside and the inside, it can be easily opened.

Either as a normal course of operation or in an emergency.



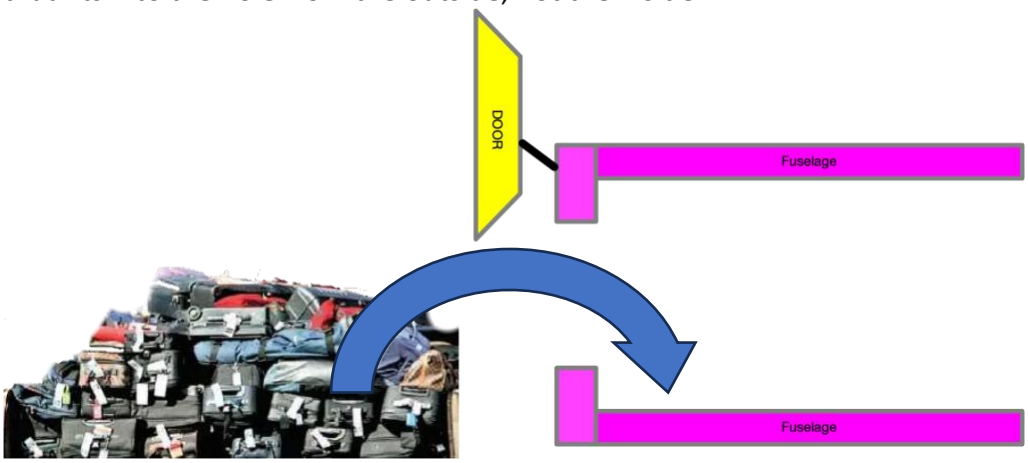
The only problem with plug-type doors of this type is that they:

a. Must open INWARDS
b. Have to incorporate hinges because they are heavy.

Now that's the story about regular doors. What about other doors like the doors used for baggage, cargo and for emergency exits?

Usually they are designed along the same principle – the door in question is made larger than the hole it is intended to cover. But this can cause problems.

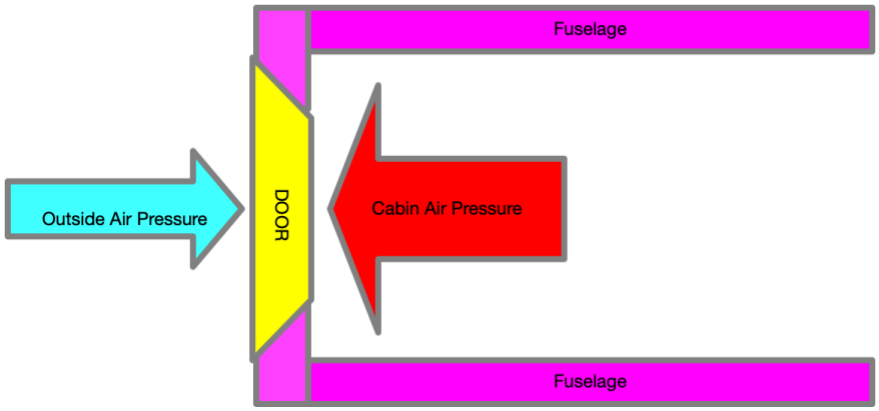
For cargo and baggage doors you would like to have a door that opens outwards and then moves up and out of the way. This means a door that is still larger than the hole it plugs but that fits into the hole from the outside, not the inside.



(luggage photo courtesy of the Denver Post)

Once you do that, you open up a whole can of – as we say in engineering texts – "whoopass."

There's no free lunch. You can't have a door that opens OUTWARD and a door that is easily, simply and securely held in its hole by cabin pressure.



So, if you absolutely must have the door open OUT, instead of opening IN, then you are going to have to do a really stellar job of engineering to make that door work right. Meaning work reliably and safely.

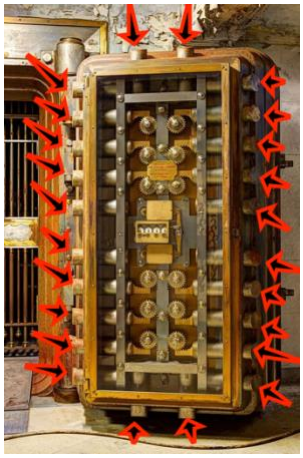
You cannot cut corners here.

In 1974 a Turkish Air DC-10 crashed outside Paris due to one of its cargo doors blowing out. The resulting rapid decompression caused the cabin floor in the DC-10 to buckle (the air pressure in the passenger cabin became much higher than the pressure in the cargo section below it).

When the floor buckled, it severed and restricted the control cables running from the pilot's controls to the control surfaces, rendering the aircraft uncontrollable.

Three hundred and forty-six people died as a result.

The cargo doors on the McDonnell Douglas DC-10 were outward-opening, in order to facilitate loading. They were kept attached to the fuselage in flight by a number of "fingers" that rotated outward and then gripped the surface of the inner fuselage. The arrangement was very similar to how many bank vault doors are secured – with heavy, stout pins that bear against the inside of the opening.



(Image from Pinterest and used without permission)

Except in the DC-10 the pins were never heavy nor stout (it is an airplane, after all).

The baggage handlers were supposed to close and secure the door by rotating a handle on the outside that forced the pins out and locked the door to the fuselage. However, the entire mechanism for doing that was rather under-built and under-designed with the result that a strong baggage handler (aren't they all?) could easily force the lever into position without the pins becoming fully engaged.

McDonnell Douglas was a company known to be intensely interested in the financial aspect of building commercial airliners and not one known to spend more on engineering than could be justified by the resultant return in investment (ROI).

MD and Boeing merged in 1996.

Commercial aircraft are required to have a number of emergency exits available for passenger egress

These exits are normally in addition to the regular cabin doors.

In the past the emergency exit doors were designed using the same “plug in a hole” principle as the main cabin doors. In other words, it was impossible for the emergency exit doors to be opened in flight as each had approximately ten thousand pounds of air pressure holding it firmly lodged in its fuselage hole.

This created some problems however. The first was that the emergency exit doors were not doors in the first place. They were just plugs. They had no hinges on which to operate. They simply “stuck” in the hole and, if air pressure allowed (i.e. on the ground) they could be easily pulled out of their holes.

Easily is a relative term. As I said they still had to hold back ten thousand pounds of force in flight. Which meant they were beefy. And heavy. So the person pulling them out had to be reasonably strong. And they couldn’t be so big that even a strong person couldn’t pull them out.

Second, because they fit from the inside, they could only go inside. Once removed the person who removed them either had to chuck them into the plane, where they could present an obstacle to evacuation. Or had to turn them awkwardly so that they would fit through their hole – and then chuck them outside.

In an emergency it was deemed that this would be unlikely to be carried out well. So a decision was made to

a) Make the doors larger
b) Hinge the doors

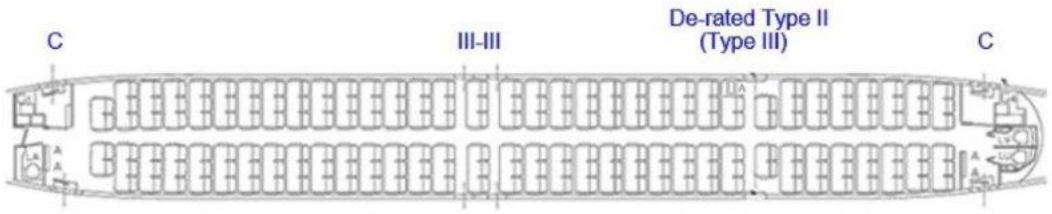
This basically meant that the doors had to open outwards, not inwards. Which meant they would have to be actively restrained in their holes by stops and latches, like the DC-10 door, not passively restrained by air pressure as was standard practice.

The simple became complex. It became expensive. This was no job for a junior engineer. And hopefully no junior engineer was given the task of designing it. And hopefully it wasn’t done on the cheap.

That’s the history. And, unfortunately, history tells us that practice today is to do it on the cheap. Including with the cheapest (i.e. least skilled) labor possible.

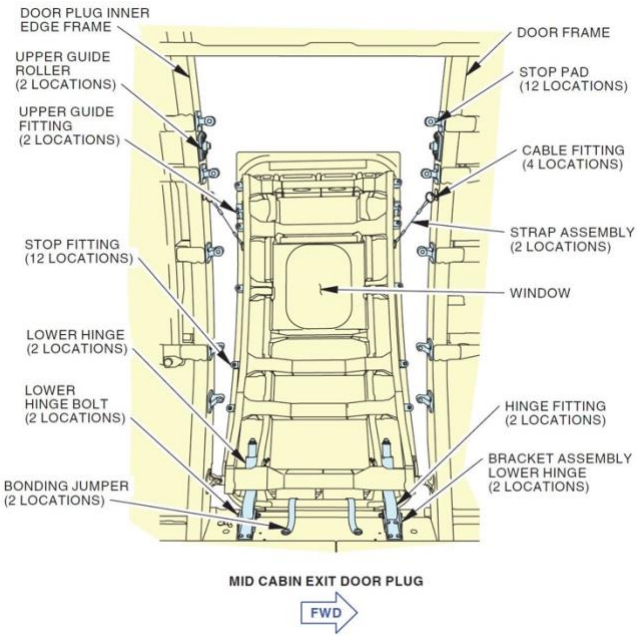
Now lets get into the accident.

The required number of emergency exit doors or openings is a function of how many passengers the airline intends to cram into the cabin. Simply, the more passengers the greater the required number of doors. Airplane fuselages are manufactured to accommodate the maximum number of doors.



737-8200 (with De-Rated Type II (Type III) Mid-Cabin Exits)
200 passenger configuration shown (210 exit limit)

If some of the emergency exit doors are unnecessary due to low passenger density then the "extra" door openings in the fuselage are covered with so-called "door plugs."



These plugs attach to the fuselage much as a real door would and are even given provisions such as small vestigial hinges which allow the plugs to be easily "opened" if necessary.

It's not clear why a decision to make the plugs so easy to open (and remove) vs. simply making them very fast and permanent.

Presumably this was done to ease certain maintenance tasks as well as to make it easy to convert from a door plug to a real door if desired in future.

Normally the door plugs are held in the fuselage against 12 "stop pads" which are forged aluminum fittings.

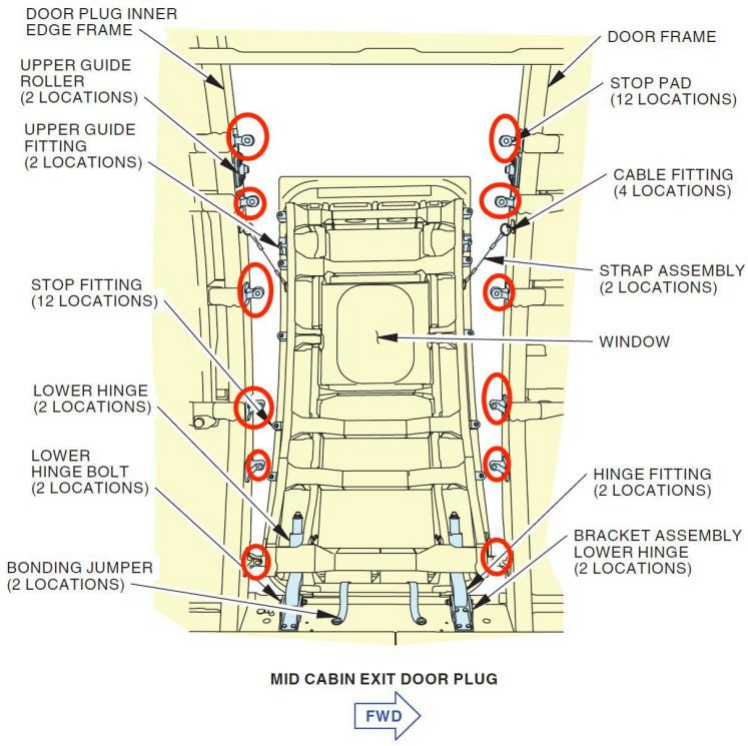
For each stop pad attached to the fuselage there is a stop pad on the door plug.

The door plug stop pads sit INSIDE the door frame stop pads.

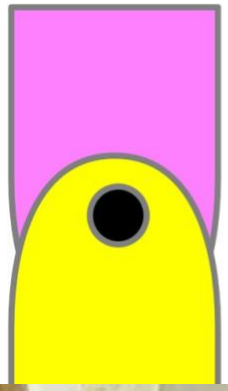
This is important.

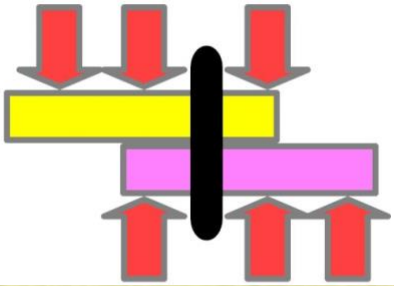
Because the door plug pads are inside the door frame pads, when the cabin is pressurized the pads press against one another.

In fact, at full pressurization, there is more than ten thousand pounds on the door plug -- equivalent of three Teslas (Tesali?) pressing down.



Here you can see how that works. The pink is the outer fuselage of the 737. Yellow are the components of the door plug itself. Specifically the “stops.”

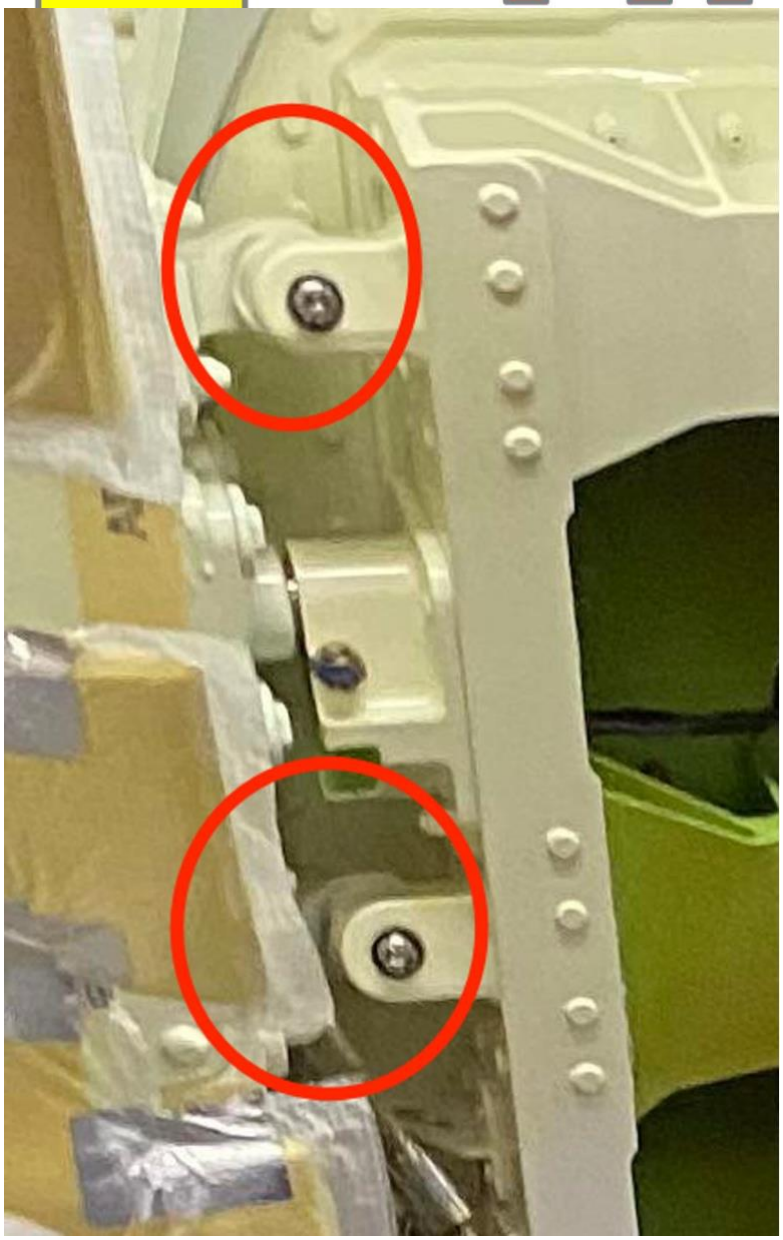




The black cylinder are the centering pins (more on those later) that are used to keep everything aligned. They are essentially dowel pins and have no structural role other than making sure the various pieces remain aligned, particularly when the airplane is *not pressurized.*

When the airplane is pressurized the pressure differential between the air inside the cabin and the air outside generates a substantial force pushing the stops against one another.

The centering pins depicted as black in the schematic diagram are easy to see as the silver round objects in this picture.



Again, in flight the pieces are pressed together with substantial force (ten thousand pounds distributed over twelve stops) and the centering pins are not necessary to keep things together.

It’s only when the airplane is unpressurized that the pins help keep things aligned and in-place.

Remember that the door plugs are designed to be relatively easy to open and remove if necessary.

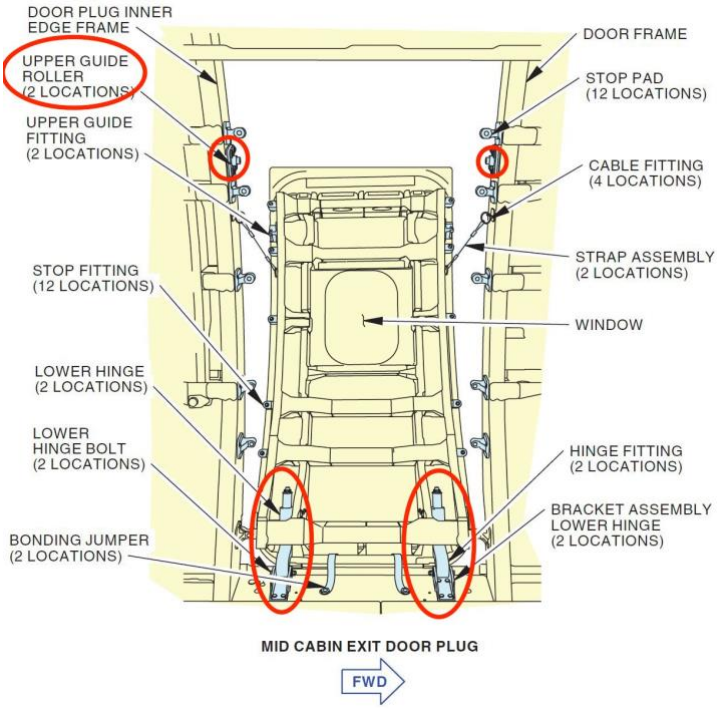
Removing the door means simply moving it UPWARDS a bit ("translating" it in engineering-speak) so that the stop pads clear one another.

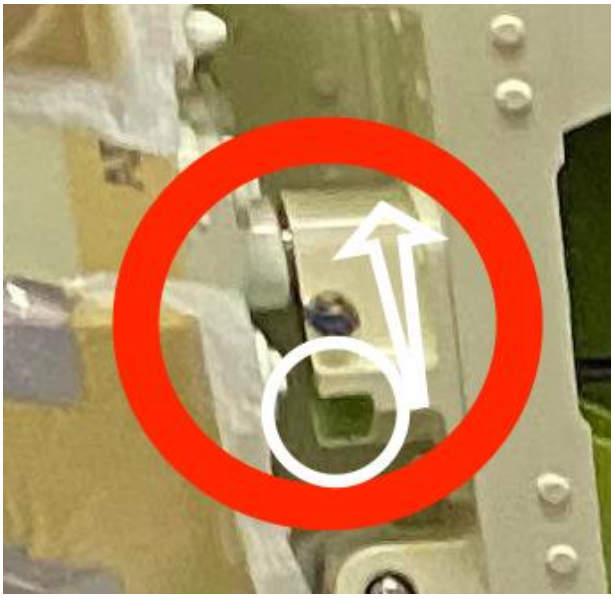
This is facilitated by hinges and guide rollers that exist only to make it relatively easy to open and remove the door plug if desired.

Ordinarily these hinges and guide rollers would not be used when the aircraft is in commercial service.

Nor are they critical to keeping the door in place during flight. That is what the centering pins are for.

The only use of the door guide rollers and the vestigial hinges at the bottom of the door are during maintenance or when the aircraft is being converted to replace the door plugs with actual doors.

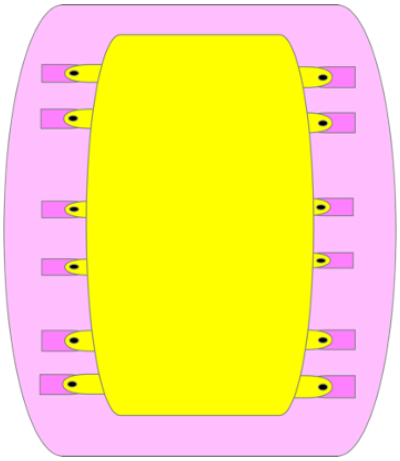


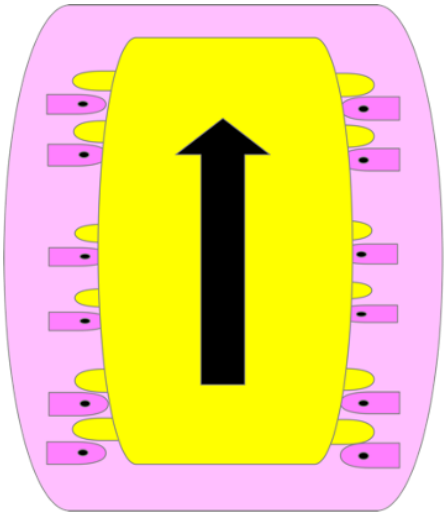


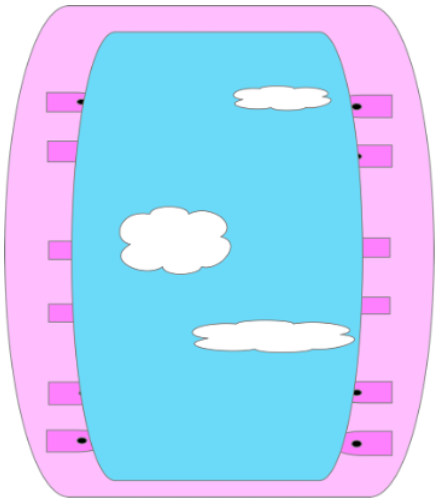
Here is a schematic of how it works (opening and/or removing the door plug)

Yellow is the door plug and pink is the fuselage surrounding it.

Now that's great for when you WANT to remove the door…

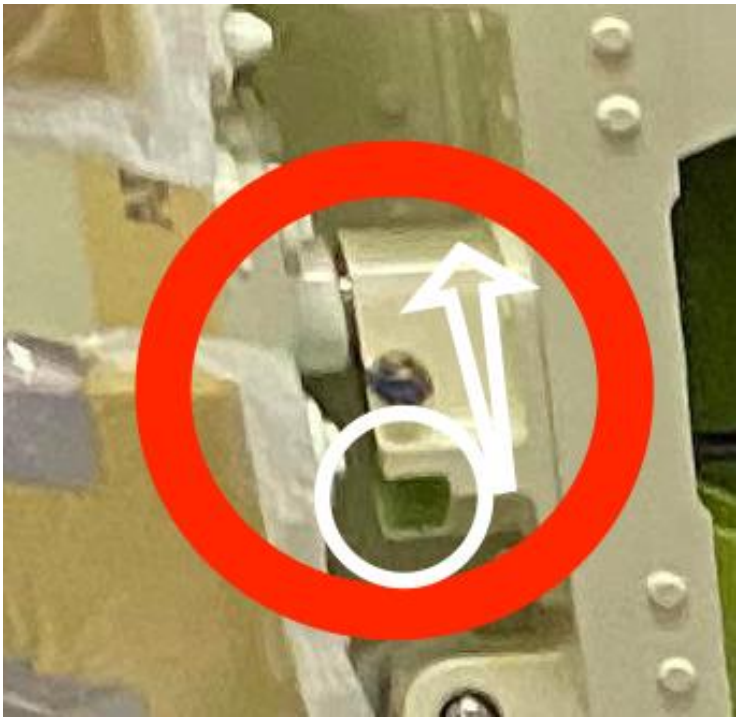






But not so great when you DON’T want the door to “open.”

How is it supposed to work when you DON’T want to open the door plug? When you want it to stay firmly attached to the airplane even though it needs to resist ten thousand pounds of force trying to blow it outside?



First is the "upper guide roller."

This is a part of the frame that makes it easy to position the door plug in place.

The door plug is "dropped" into this guide from above, facilitated by the translating (movable up and down) hinges at the bottom.

Note this detail of the "upper guide roller" components.

There is a notch at the bottom of the fitting in the door plug.

This allows the guide pin to exit out the fitting when the door is raised.

And a bolt through the fitting that does not allow that to happen normally.

During assembly, the door plug is closed using small hinges at the bottom (FYI a real exit door in this location is hinged at the top, not the bottom, using a big hinge).

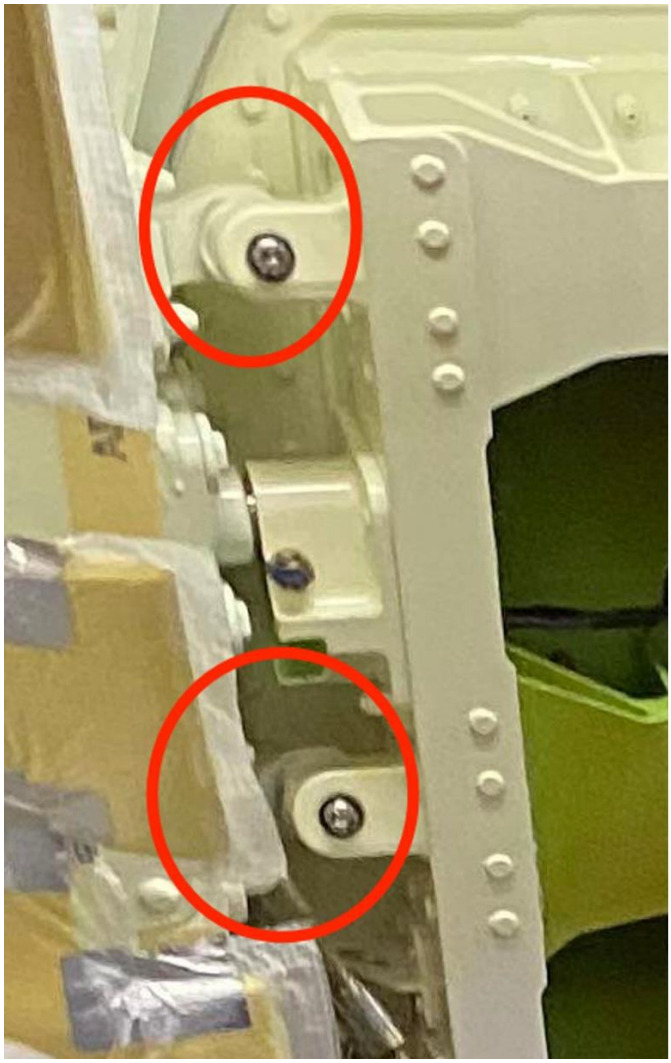
And then dropped onto the roller through the notch.

Whereupon the bolt is inserted to secure it.

However just two small bolts to secure the door plug in the upper guide rollers would not be sufficient.

So each of the door stop pads is also fitted with a kind of bolt -- to keep it in place.

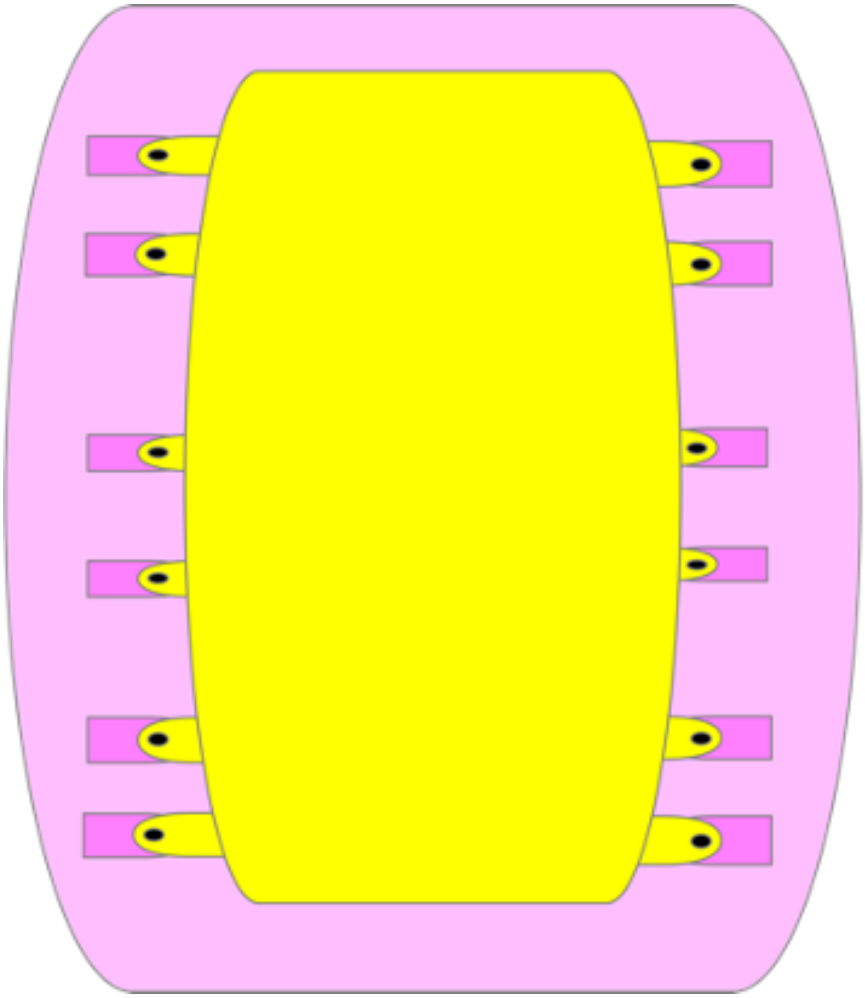
I can't find a name for these fittings so I will simply call them "centering pins."



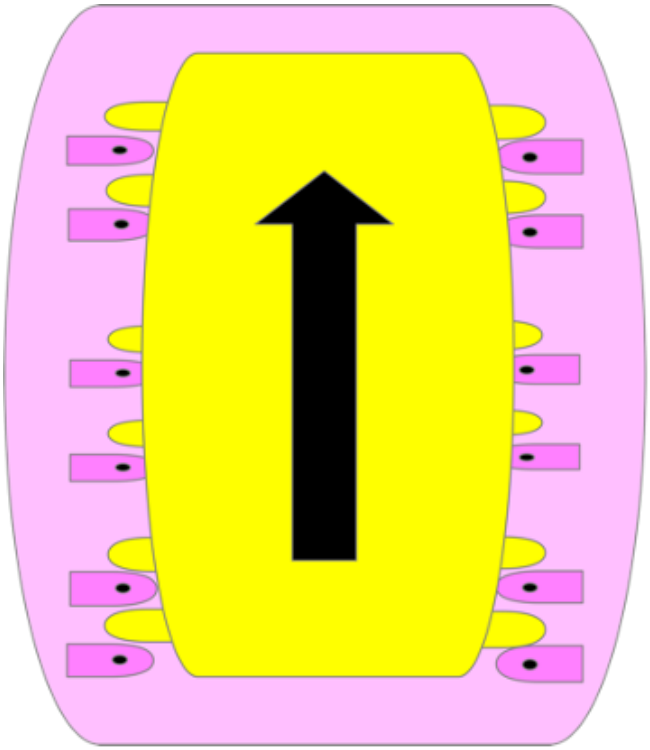
For the door plug in the Alaska Air flight to have departed the aircraft it needed to move up, before it could move out.

But it should not have been able to move up. The centering pins should have prevented any upward movement.

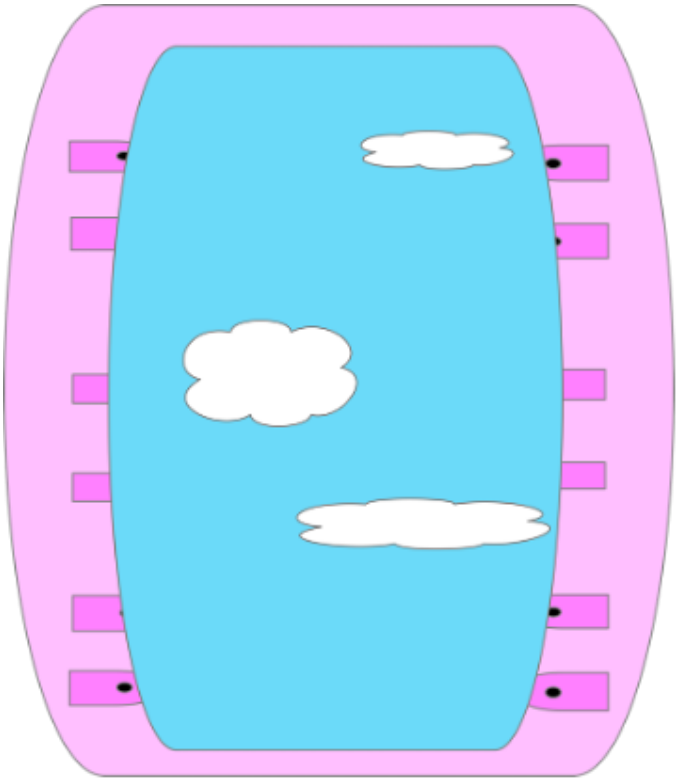
It should have been stopped by the bolt in the upper guide roller and/or the centering pins.



Obviously it was not because on January 6th, 2024 this:



Became this:



We know that the stop pads themselves were relatively undamaged. They did not fail.

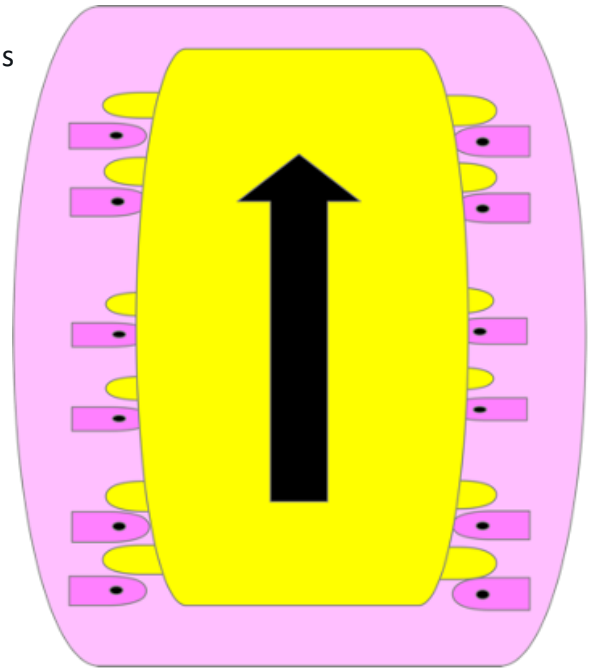
The only way the door plug could have come out is either if its stop pads failed (need to find that plug!) OR if it *moved up and out*.

Given that this design is decades old and has given trouble-free service in those decades, it is unlikely that this is the result of a design error.

The most likely explanation, at this point, is that the centering pins necessary to keep everything aligned either failed for some as yet unexplained reason.

Or they were misinstalled at the factory when the plane was built (the plane was a mere ten weeks old at the time of the accident).

Or they were never installed in the first place.



Questions

A. Given this design is decades old and has never given this kind of trouble, was this a manufacturing defect in this one particular airplane (i.e. missing centering pins)?

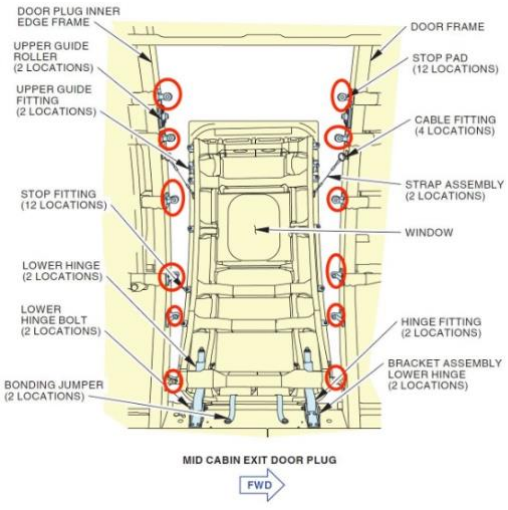
B. Why make the door plug so easy to remove versus a more permanent fuselage attachment?

1/9/2024 Update

The media has picked up a narrative that the door plugs filling unused exit door holes in the fuselage are secured with merely “four bolts.” This is incorrect.

A photo showing the type of door plug fitted to a Boeing MAX 9 aircraft that fell off Alaska Airlines flight 1282. It's secured to the airframe by two bolts at the top and two at the bottom. (Courtesy of Chris Brady at b737.org.uk)

https://www.seattletimes.com/business/boeing-aerospace/united-finds-loose-bolts-on-door-plug-when-inspecting-its-max-9s/



The door plug is held in place by twelve sets of "stop pads.” Twelve are secured to the door frame & the other twelve are secured to the door plug.

When assembled, the stops press against each other.

It is these stops which resist the ten thousand pounds of pressure on the door.

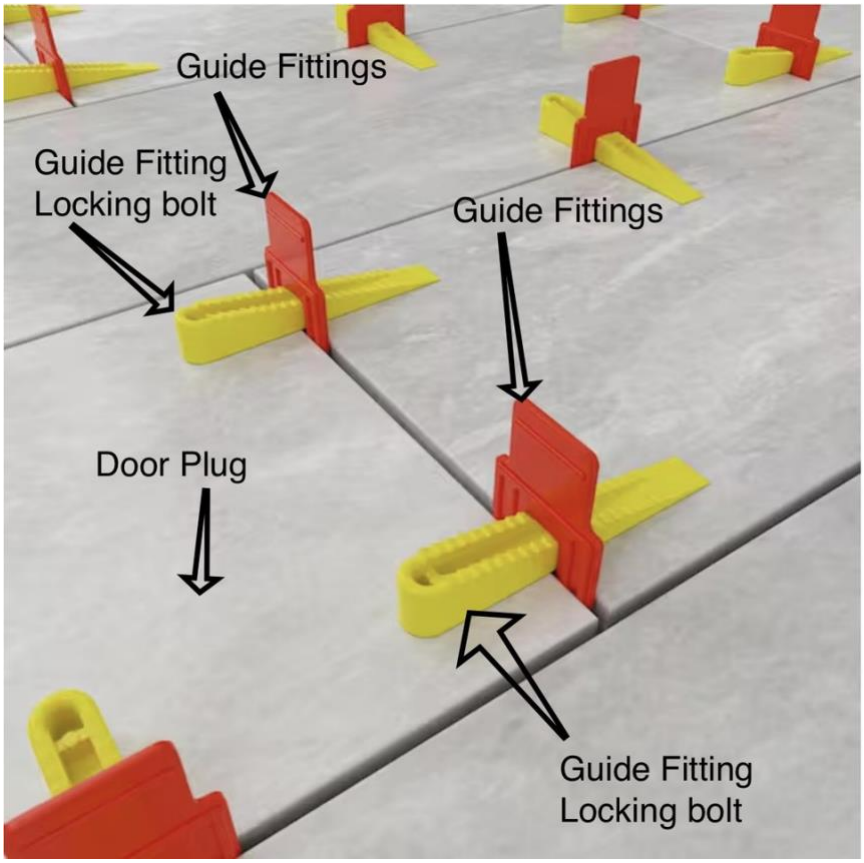
The bolts referenced by Gates do not hold the door plug in.

Again, there is ten thousand pounds of force on the door in flight.

Four tiny bolts are not going to do that job.

The bolts are safety devices, used to ensure that the door does not move out of its guide fittings once it is placed in the fuselage hole and when there is no cabin pressurization to hold it firm against the stop plugs.

Think of the guide fittings like the spacers used between bathroom tile that keeps the tile aligned on the wall while the glue that holds it to the wall cures.



This is important because "a few" bad bolts could easily be used to minimize what happened.

Did the bolts arrive at Boeing/Spirit faulty? Not Boeing/Spirit's fault.

It goes deeper than that. If it is true (it is not) that only “four bolts” hold the door plug to the fuselage then those four bolts become the target of the investigation. Boeing can then easily play this incident off as a one-off because this door plug design came about in the mid 1990s – thirty years ago – and it’s never been a problem in the past to secure these plugs with just four bolts.

In other words, a four bolt attachment system is not actually a bad design (it would be). What this does is inject noise into the public sphere, using the media as the megaphone. It creates a veil of plausible deniability that this incident was symptomatic of some kind of widespread malignant cancer within the Boeing and Spirit organizations that prevent them from being able to design, assemble and test safe aircraft.

Instead it lays the foundation for this incident as being not chronic but an acute failure of one door plug on one airplane. Not all the door plugs on all the airplanes.

It's a distraction from the serious quality control issues @ Boeing/Spirit.

It's being manufactured deliberately.

Update 1/10/2024

The missing door plug has been found and it is clear that the centering pins are intact and installed although with the picture I have it is very difficult to ascertain their exact condition.

Ordinarily the design of the door plug should make it absolutely impossible for the plug to translate upwards and then out of the airframe if these stops and their centering pins are aligned with and inserted into the female mating holes in the stops in the door frame. Irrespective of whether or not the two bolts retaining the guide slots at the top are installed or not.

This is a current narrative and it is distracting and wrong. If the door plug has its stops, its stops have their centering pins and the centring pins are inserted in the female recepticals in the associated door frame stops, the door cannot move or depart the airframe.

Full stop.

The only way it could is if the door was installed misaligned in the first place. And that that misalignment somehow escaped every quality control and safety check, including an examination OUTSIDE the airplane to see if the door plug was properly aligned with the opening in the fuselage in which it fit

Five years ago a number of us warned that the errors and oversights that led to the Boeing 737 MCAS tragedies were so egregious and so vast in scope that it was impossible for the 737 MAX to not have many many more defects of the same nature

That nature being the relentless cost-cutting, outsourcing and financialization at Boeing, largely as a result of the reverse takeover of Boeing in the 1996s by McDonnell Douglas We petitioned the FAA as well as Boeing and others to be relentlessly transparent in the re-certification process and not to hold Boeing to the same series of self-regulation, regulatory capture and secret actions that had led directly to the MCAS tragedies

We were assured by the FAA and Boeing that they would be open and transparent, this time

When it became obvious that they meant that as mere "puffery" and that they were under no obligation to actually be transparent we sought relief under FOIA The courts rejected our FOIA request on the basis that Boeing had an inherent right to secrecy in developing its products and the FAA had an inherent duty to protect Boeing's secrecy.

The author of the Salon piece, Marshall Auerback, and I wrote a small airticle on the matter for *Naked Capitalism* entitled "**Anatomy of a Disaster – Why Boeing Should Never Make Another Airplane, Again**." We argued that pressures to meet Wall Street earnings expectations had utterly transformed Boeing's culture making it incompetent to deliver safe commercial airliners. We also noted: "Another issue that hasn't gotten the attention it warrants is that Boeing appears to lack the stringent software development protocols necessary for 'fly by wire' operations."

I detailed the technical, architectural and cultural factors at play within Boeing that explains the forces within Boeing that led to the development of the deadly MCAS system in "Ship the airplane: The cultural, organizational and technical reasons why Boeing cannot recover". Finally, I explained why the process of outsourcing the FAA's regulatory oversight function to Boeing itself was doomed in "How self-regulation fails: The Boeing Case."

In response to the intense public backlash over the lack of FAA oversight as well as lawsuits from shareholders and criminal charges against Boeing for lying about MCAS, both the FAA and Boeing made overt pledges to moving forward with openness and transparency with regard to re-certification of the 737 MAX:

> *"The Federal Aviation Administration (FAA) is promising to share information about its efforts to ensure that proposed changes to the automated flight control system on the 737 MAX meet certification standards."*
>
> Industrial Safety and Hygiene News, "FAA Pledges Transparency in Boeing 737 MAX actions" September 2019

> *"In a message to employees, Boeing's new chief executive, David Calhoun, who started work Monday, pledged greater transparency at a company still reeling from two crashes that killed 346 people and led to harsh scrutiny of the company's corporate culture."*
>
> Washington Post, "Boeing's new CEO pledges greater transparency in message

PR Newswire Send a Release

FlyersRights.org and Aviation Experts Ask Federal Court to Break FAA and Boeing's Secrecy Pact and Release 737 MAX Documents

NEWS PROVIDED BY FlyersRights.org →

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The request for FAA disclosure is supported by a wide array of independent aviation experts and interests, including:

Michael Neely (20 years with Boeing as a system engineer and project engineer),

Javier de Luis PhD (30 years of experience as an aeronautical engineer and manager, MIT lecturer),

Richard Spinks (38 years of experience in process safety, automation engineering),

Dennis Coughlin (31 years of experience as an avionics technician and instructor),

Ajit Agtey (40 years of experience as an airline and military pilot, and former Chief Test Pilot of the Indian Air Force)

Daniel Gellert (50 years as a commercial airline pilot, Boeing test pilot, and FAA official),

Geoffrey Barrance (30 years experience as an avionics, air frame and safety engineer),

Gregory Travis (over 30 years experience as a computer software scientist/executive, private pilot)

Chesley "Sully" Sullenberger (37 years experience as an airline and military pilot, 10 years as an aviation safety consultant and author, celebrated for successful landing of a disabled airliner in the Hudson River)

Michael Goldfarb (over 30 years experience as aviation safety consultant and former FAA aviation safety policy official)

And that the public had no right to see, much less understand the circumstances under which the machines that they count on to transport them safely from one place to another were, indeed, safe.

History is repeating itself

As we predicted it would if allowed to by a government the public had entrusted to protect it was allowed instead to continue to operate opaquely and to the financial benefit of well-lobbied corporations.

The door plug design of the 737 is not inherently bad nor is it not “fail-safe.” We know this because that particular design has been in use since 1996 and has logged millions of safe flight hours since It is actually difficult, not easy, to install the plug incorrectly.

And even if installed incorrectly, even the most basic of safety oversight and quality control checks would immediately spot any installation discrepancies The only way that plug can fail, in the way it failed, is as a result of egregious flaws in the manufacturing process.

The FAA’s response

The FAA justified withholding the above information on the following bases:

- Pledges of transparency were made within the legal doctrine of puffery. “Puffery” is often invoked as a defense in criminal fraud trials where it is asserted that statements of fact made by the defendant were instead merely boasts, exaggeration and even outright lies that the defendant uttered and not to be taken as evidence against the defendant.

  In other words, FAA argues that the FAA and Boeing’s public commitment to complete transparency after two accidents killing 346 people, for which Boeing has been criminally charged for lying and the FAA roundly criticized for being asleep at the wheel,

were not to be taken seriously.

- The withheld information constituted “technical trade secrets” of Boeing’s that if revealed -- even the FAA’s own comments – could or would harm Boeing’s competitiveness in the global airliner manufacturing market.

- The FAA did not hold Boeing’s re-certification to its meeting the regulatory requirements of Part 25. Instead, after the crashes that resulted from Boeing’s own self-regulation, the FAA allowed Boeing to write its own, new, version of Part 25’s certification requirements as well as the criteria necessary to meet those requirements for re-certification.

Like letting a car leave the factory while forgetting to attach the axels to the frame

We predicted, five years ago, that such manufacturing flaws would repeat if nothing was done to change Boeing's corporate culture or the culture of the FAA that enabled Boeing’s behavior

History has now repeated itself

Update 1/11/2024

Alaska Air has issued the following statement:

> *Latest Update: 10 a.m. Pacific, Jan. 10*
>
> *As of today, Wednesday, Jan. 10, Alaska Airlines continues to wait for documentation from Boeing and the FAA to begin inspection of our 737-9 MAX fleet.*
>
> *We regret the significant disruption that has been caused for our guests by cancellations due to these aircraft being out of service. However, the safety of our employees and guests is our highest priority and we will only return these aircraft to service when all findings have been fully resolved and meet all FAA and Alaska's stringent standards.*
>
> *As of this morning, we have made the decision to cancel all flights on 737-9 MAX aircraft through Saturday, Jan. 13 while we conduct inspections and prepare fully for return to service. This equates to between 110-150 flights per day. We hope this action provides guests with a little more certainty, and we are working around the clock to reaccommodate impacted guests on other flights. More information for impacted travelers can be found at the bottom of this page.*
>
> *As a reminder, three things must be in place prior to beginning inspections:*
>
> ◦ *A final Multi-Operator Message (MOM) provided by Boeing, providing inspection details for the 737-9 MAX aircraft as approved by the FAA.*
> ◦ *An Alternate Methods of Compliance (AMOC) published by the FAA with details for approval of operators' inspection processes to ensure compliance with their Airworthiness Directive. As a party to the NTSB investigation, the FAA works to ensure that inspection details address findings that may have surfaced during this process, even if not yet shared with the public.*
> ◦ *Detailed inspection instructions and processes developed by Alaska Airlines for our maintenance technicians to follow to conduct thorough inspections per the FAA's specifications.*
>
> *We will continue to provide updates as progress is made.*

It has now been five days since a door plug (not a door) broke free from a 737 MAX 9 fuselage at sixteen thousand feet over Oregon. The resulting explosive decompression blew open the cockpit doors (remember: they are normally tightly secured following the 9/11 hijackings) and literally ripped the shirt off of a young man sitting in the same row as the departed door plug.

The fuselage stops that are supposed to retain the door plug were found intact in the fuselage and relatively undamaged. The door plug itself has been recovered and is, from what we can tell, in near pristine shape also. In other words neither the fuselage structure nor the door plug appears to have suffered any type of structural failure that would explain why the door plug, which is under roughly ten thousand pounds of pressure in flight, was not retained in the fuselage as designed.

That there is no obvious “smoking gun,” especially given that the aircraft in question was recovered wholly intact with no loss of life (i.e. there are hundreds of first-hand witnesses to what happened) and that there is no obvious structural failure to explain why the plug departed is chilling. It is eerily reminiscent of the “fog of war” that surrounded the first and then the second 737 MAX fatal crashes in 2018 and 2019.

As is the tone and tenor of the official response. A tone and tenor that I describe as “telling the truth but telling it as slowly as you can get away with.”

It is clear to me, at this point, that the door plug was simply not installed correctly in its fuselage fittings. Not only was it not installed correctly but the incorrect installation “escaped” (Boeing’s term) the numerous quality control

checks that should have accompanied such an important fuselage component – given the chance and likelihood of a serious accident with loss of life should it be installed incorrectly.

And while some aviation journalists like to assure us that they “speak Boeing” when they tell us that “escaped” is Boeing-speak for “was not caught by inspection” then they need to go back to the Boeing Duolingo app and try harder.

Because there cannot be escape from an inspection process if that inspection process doesn’t exist in the first place.