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LONG FORM

Why Did The Boeing 737 Max Crash?

When an airplane falls out of the sky, everybody stops. Families cry. Friends grieve. Journalists race to the scene. And all of us turn to the news.

Airplane crashes capture an outsized share of attention. Even though they represent a small fraction of transportation-related crashes, their rarity and drama hold a steel grip on our hearts and minds. But what if we could understand the systemic issues that cause certain airplane crashes?

The airline industry has a strict process for evaluating accidents to prevent future ones. Immediately after a crash, a team of investigators observes the aircraft, studies the scene, and replays the pre-crash commentary from the cockpit.

That's exactly what happened with two recent Boeing 737 Max crashes, which led to the deaths of 346 total people. The first crash happened in October 2018 when Lion Air Flight 610 crashed 13 minutes after takeoff and killed all 189 people on board. Then, in March 2019, Ethiopian Airlines Flight 302 crashed and ended another 157 lives. Three days after the second crash, the United States government grounded all Boeing 737 Max airplanes. As I write this, the airplane is still barred from flying in every country.

The more I studied the crash, the more I realized the media wasn't telling the full story. That's the purpose of this essay.

Why did the 737 Max crash? Because of a software failure.

Why did the software fail? Because Boeing's executive team has lowered its engineering standards.

Why did Boeing lower its engineering standards? To lower costs and increase efficiency — the goal was to save money.

Why does Boeing save money at the expense of human lives? Because Boeing purchased McDonnell-Douglas in 1997 and absorbed its ultra-corporate culture with relatively low engineering standards. Since the acquisition, the company hasn't innovated as fast as it

once did. In lieu of actual innovation, the company cut corners to maintain growth rates.

Why did Boeing buy McDonnell-Douglas? Because the airplane manufacturing industry is consolidating, and Boeing is pursuing profit at the expense of human lives.

The actual story of the 737 Max crash begins with that McDonnell-Douglas purchase in 1997, 21 years before the first accident in late 2018. Unfortunately, media coverage of the crash mostly ignores Boeing's corporate history.

This is more than a story about two airplane crashes. It's a story about an iconic American giant that lost its way because of mergers, risk-aversion, and excessive outsourcing.

Fasten your seat belts, put your seat in the upright position, and prepare for takeoff.

Mergers

The airplane industry has been shaped by a series of recent mergers. By consolidating big airplane manufacturers into even bigger ones, those mergers have reduced industry competition.

Duopolies slow innovation. Any economist will tell you competition is the spark that propels innovation. When there is no market competition, the rate of innovation declines. If you need further proof, look at the regulated utility companies that power the gas, energy, and internet for your home. And year after year, companies like Verizon and PG&E have the lowest customer satisfaction rates of any sector in the economy.

Mergers lead to a risk-averse culture

Industry concentration necessarily leads to a risk-averse culture. Companies don't have to innovate when they know they won't go out of business, because the incentives of the organization shift from driving the technology forward to not messing anything up.

Until it acquired McDonnell Douglas in 1997, Boeing had a reputation for speed and innovation. For example, the 747 took its first flight just 930 days after Boeing decided to start the program.

In the case of Boeing, power has shifted from build-hungry engineers to blue-suit executives. As recently as 2000, [one journalist wrote](#): "Boeing has always been less a business than an association of engineers devoted to building amazing flying machines."

Boeing's culture has lost its progress-hungry mindset. Today's executives don't have Charles Lindbergh's pioneering spirit or the Wright Brothers' hacker mentality.

[Boeing critics say](#) the company adopted excessive outsourcing practices after the 1997

McDonnell Douglas merger. In the battle between finance and engineering, the money men walked away with the boxing belt.

Boeing adopted McDonnell Douglas' culture of risk aversion and cost-cutting. Instead of pursuing aggressive product development, Boeing ran the business for cash. By moving its headquarters from Seattle to Chicago, Boeing ensured the CEO would sit more than 2,000 miles away from the engineers who cut the wires and tightened the screws. To this day, industry insiders still joke, "McDonnell Douglas bought Boeing with Boeing's money."

In 2005, Boeing hired its first CEO without aircraft engineering experience. Slowly, the company lost its culture of engineering excellence and adopted one of financialization and cost reduction through outsourcing. To illustrate the dangers of outsourcing, Smith points to the DC-10 aircraft, where the subcontractors made all the profits while the McDonnell Douglas absorbed the excess costs. In the aircraft industry, outsourcing commercial aircraft is likely to backfire. Military aircraft are a major exception because Congressional support is easier to secure when many states are involved.¹

For all the chatter about the problems with industry concentration, nobody talks about the Boeing-Airbus duopoly.² If you've flown on a commercial jet with more than 150 seats, you can bet it was made by one of these two companies. They have near-equal share in the market for single-aisle jets, which Airbus values at \$3.5 trillion over the next 20 years.

Here, I want to draw a line between two parts of the airline industry: airlines and airplane manufacturers.

From 2005 to 2017, the number of major airlines in America dropped from nine to four. And yet, during that time, inflation-adjusted prices fell and the total number of miles flown in the United States increased. Airline tickets for the five American major carriers — Delta, United, American, Alaska, and Southwest — began to be pushed downwards because of competition from a litany of low-cost carriers. Moreover, in individual city markets, airline concentration **is not increasing**. Competition among airlines is still relatively intense.

But in the market for purchasing airplanes, Boeing is the only major American manufacturer. Unlike the market for flights between Chicago and San Francisco, the market for airplanes is global.

Even though Boeing and Airbus fight for market share, they don't want the duopoly to end. Even when a market window opened after the Boeing 737 crashes, Airbus didn't exploit it. As one [Reuters article said](#), "Airbus is wary of exploiting Boeing's misery... Airbus isn't pouncing on Boeing's 737 Max turmoil." Pending any major safety issues, both businesses are safe from existential threats. Any big changes, such as a price war or a radical new jet, could destabilize the industry, but the shares of both aircraft manufacturers have skyrocketed over the past decade.

Those mergers had a dangerous side effect: risk aversion.

Risk Aversion

In a culture of risk aversion, people hesitate to make necessary but impactful decisions which re-orient the company. To avoid blame, higher-ups and employees reject bold visions

and adopt a status quo bias.

In similar fashion, grant approvals for scientists have to pass through layers of approval. By the time they reach the end of the grant approval process, the ideas are watered down to the point of [triviality](#). Paradoxically, the kinds of projects you can receive a grant for are probably too conventional. Transformative change is usually unpopular. But when you apply for a grant, the need to adapt to social conventions make it difficult to pursue paradigm-shifting work. Innovation slows and like the Boeing 737, necessary changes aren't made.

HISTORY OF THE BOEING 737

To understand why these airplanes crashed, we need to explore the history of the 737.

The original 737 took its first flight in 1967, back when jet fuel was cheap. At the time, people didn't understand the implications of pollution, so environmental concerns were an afterthought. Most airports were small and rural. They lacked infrastructure, such as jet gates and fancy luggage-loading machinery. In response, airlines asked manufacturers for low-to-the-ground airplanes with easy-to-reach engines, which reduced operating costs. And that's exactly what Boeing gave the airlines.

The 737 Max's structure resembles the original 737. The big difference is the engines are larger, the fuselage is bigger, and "winglets" were added to the tip of the wings to improve fuel efficiency.

By all accounts, the 737 fleet has been a smashing success. In 2005, more than 25% of all large commercial airliners were Boeing 737s. However, the recent crashes demonstrate the challenges of modernizing the Boeing 737 fleet.

How did risk aversion cause the crashes?

The (very) basic background story goes like this: The Boeing 737 is a victim of its own success. The airplane thrived for more than half a century during a period when airplanes were safer and more automated. The 737 brand was so trusted that when aircraft upgrades were needed, Boeing re-designed the 737 instead of creating a new fleet of airplanes.

As Stan Sorscher, a [former Boeing engineer](#) and a labor representative at the Society for Professional Engineering Employees, said:

"The cost-cutting culture is the opposite of a culture built on productivity, innovation, safety or quality. Boeing's experience with cost-cutting business culture is apparent." He continues, "... Production problems with the 787, 747-8 and now the 737 Max have cost billions of dollars, put airline customers at risk, and tarnished decades of accumulated goodwill and brand loyalty."

Sorscher tells a story about producing the Boeing 777 in the 1990s — before the McDonnell Douglas merger — when a Boeing executive was so close to the engineering process he left the plant with grease all over his thousand-dollar suit. The decision to reduce costs and speed up 737 Max production led directly to the crashes. Re-designing an airplane from scratch would take too long, so Boeing built upon the 737's old and outdated design instead.

More seeds of the 737 Max crashes were sown in 2011 when American Airlines announced their plans to purchase 460 jets from Airbus. Boeing executives were shocked. American Airlines had been an exclusive Boeing customer for more than a decade. At the time of the decision, Boeing planned to build a new jet to replace the aging 737. But after the news, Boeing changed gears. Building a new airplane would cost too much money and take more than a decade to build. To win over American Airlines, Boeing scrapped the new airplane and made a plan to re-engineer the Boeing 737 instead. Thus, the Boeing 737 Max was born.

The Boeing 737 Max had other advantages. Had Boeing released a new aircraft, pilots would have had to train for it by spending time in flight simulators, which would have cost more money. By limiting the changes to the 737, Boeing averted those requirements and saved on expensive pilot training.

Speaking about the project, [one Boeing engineer said](#): “Any designs we created could not drive any new training that required a simulator...That was a first... There was so much opportunity to make big jumps, but the training differences held us back.”

To compete with the Airbus A320-NEO, the Max had larger engines than previous 737 models. They were designed for greater range and fuel efficiency but came with a tradeoff. Since the 737 sits so low to the ground, Boeing had to change the position of the engines on the wing to give the plane ground clearance and account for the extended length of the fuselage.

But by solving an old problem, Boeing created a new one. The new engines were too big to fit in their traditional spot under the wings. To combat the problem, Boeing mounted them forward on the wings. Moving the engine position forward shifted the plane’s center of gravity, which altered the aerodynamics of the aircraft. The position of the new engines pulled the 737 tail down, pushed its nose up, and put it at risk of stalling. (Slow air speed and high nose position are the most common causes of stalls. When an aircraft stalls, it begins to fall because the wings stop creating lift.)

Boeing installed extra software to make the updated 737 fly like traditional ones. It was designed to prevent stalls, compensate for the position of the engine on the wing, and force the aircraft’s nose down automatically when the sensors determined the airplane was flying at a dangerous angle.

The stall-prevention system (known as MCAS) was poorly designed and implemented. Since it was intended to work in the background, Boeing didn’t brief pilots about the software or train them in simulators. The software didn’t activate when the flaps were down or the autopilot was on.³ And when the MCAS system went haywire, pilots could deactivate it with a switch on the center pedestal of the 737 cockpit. As pilots yoked the airplane upwards, the software automatically pushed the aircraft nose back down. This led to the crash of the two Boeing airplanes.

Simple directions flowed from the executives to engineers: Reduce costs, finish the airplane fast, and don't change the airplane too much.

To be clear, I'm arguing we should experiment with new aircraft designs. After all, safety isn't the only way to improve aviation. Increasing speed and fuel efficiency will reduce costs, propel the economy, and reduce pollution.

But once we commit, safety is the number one goal. Airplane crashes are deadly, and we should do everything we can to avoid them. Boeing should have rigorous safety standards, and pilots should follow protocol whenever possible. With that said, Boeing needs a separate division to experiment with radical ideas such as supersonic passenger airplanes and small jets that could land and take off in cities.

Intra-city jets would reduce commute times and decrease urban congestion. They would propel the economy and boost personal satisfaction. [According to one study](#), adding 20 minutes to your commute reduces job satisfaction as much as a 19-percent pay cut. [Another one found](#) that U.S. cities with non-stop flights to Silicon Valley benefit from increased venture capital investment. It found that "a new daily flight from Silicon Valley to an international city leads to \$23 million of additional VC raised by startups in the region." Beyond that, time with friends and family is limited more by travel times than distance.

Making transportation faster and more convenient is a near-guaranteed way to improve quality of life.

Instead of dreaming up new ideas, Boeing pours its resources into incremental designs. Boeing executives knew the Boeing 737 design wouldn't work with the larger engines. But instead of swallowing some short-term risk for long-term gain and building a new airplane from scratch, Boeing did the "safe" thing and iterated upon the existing 737 line.

Pushing the frontier of engineering is risky. Doing so will challenge long-held doctrines in the airline industry and inspire whispers from gossipers who doubt the project's viability.

The airplane industry suffers from a lack of innovation. The basic design of airplanes hasn't changed in more than 70 years. When innovation disappears, companies are incentivized to engage in exactly the kind of behavior that led to the 737 Max crash. As Sorscher wrote:

"The last great innovation capable of driving major growth in aviation was the jet engine back in the 1950s, and every technological advance since has been incremental. And so the emphasis of the business is going to switch away from engineering and toward supply-chain management. Because every mature company has to isolate which parts of its business add value and delegate the more commodity-like things to the supply chain. The more you look to the market for pricing signals, the more the role of the engineer will shrink."

Certainly, there is some path dependency. Engineers are familiar with the standard design and might not want to work on something new. With that said, I'm always surprised by the difference between "airplanes of the future" and the standard designs that actually come. Even the Boeing 787, which was hailed as a revolutionary new aircraft, doesn't look different to a casual observer.

Instead of innovating on performance, Boeing innovated on process. Since former Boeing CEO James McNerney spoke against "moonshots" in aircraft development, Boeing's new airplanes don't fly any faster than their predecessors. The technical chops for supersonic travel didn't come from Boeing. It was only made possible by a partnership between Britain and France which led to the creation of the Concorde.

Airplanes reached peak speeds with the Concorde. At its peak altitude of more than 60,000 feet, passengers gazed at the tilt of the earth. Piercing through the thin air, the Concorde out-raced the spin of the earth. At about 1,300 miles per hour, the Concorde was a magnitude faster than the Titanic. What once took 137 hours by ship took 3.5 hours on the Concorde. In fact, the trip from New York to Paris was so fast that passengers barely had time to watch the movie *Titanic*.

Sadly, the Concorde stopped flying in 2003, which marked the end of a spectacular chapter in human history. The popular narrative blames the crash of Air France Flight 4590 for the end of the Concorde.

But [Eli Dourado](#), the former head of global policy at a supersonic aircraft company called Boom Aerospace cites another reason: The airplane wasn't profitable. Maintaining a small fleet of 14 airplanes cost too much because airlines required spare parts and a team of specialized technicians to keep the plane in service. Even though we have the technology to travel at supersonic speeds, all commercial flights today move slower than the speed of sound.

Instead of lobbying Congress to reduce restrictions on supersonic travel, airplane companies use political clout for zero-sum endeavors such as reducing competition from foreign airplane manufacturers.

By dropping its engineering-led culture, Boeing compromised safety standards, leading Boeing's former chief financial officer to say don't "get overly focused on the box" in an interview with Bloomberg in 2000. By "the box," she meant the airplane. To engineers, the box is everything. But it's a means to an end for detached corporate executives.

For a parallel, consider the rocket industry. Ten years ago, it suffered from the same industry concentration that plagues aviation. NASA wasn't innovating like it used to, and many people doubted it was still possible. SpaceX changed that. By injecting rocketry with a spirit of innovation, the company ignited the space industry. Spurred by Elon Musk, investors are pouring billions of dollars into the space industry. Unfortunately, the major airplane manufacturers have no such visions.

Maybe Boeing knows something I don't. Perhaps we're close to peak efficiency in aircraft design. If that's the case, experimentation doesn't make sense. But until I see some radical new experiments fail, I don't buy the argument. Unfortunately, Boeing won't take on a project unless it has a near-100% chance of success.

Outsourcing

Even as a small kid, I loved big machines. In 2006, when I was in 6th grade, I conducted a research project on the Boeing 787. Sensing my commitment for the project, my father surprised me with a trip to Seattle to tour the Boeing factory. During our visit, we geeked out about the in-cabin lighting, the large windows, and the ultra-light composite fuselage.

We learned the 787 would be built of carbon-fiber composites instead of aluminum, which would make the airplane significantly lighter than its predecessors. Instead of running on pneumatics, the 787's braking, pressurization, and air-conditioning systems would run on lithium-ion batteries and use 20% less fuel than similar airplanes.

According to my father, one Boeing employee at the factory told us he had reservations about the 787. Since so many parts would be built internationally, he anticipated problems with quality control.

During our visit, Boeing employees told us the airplane would be completed within two years. Then, the delays came. Boeing famously outsourced many aspects of the airplane construction process. Instead of building the 787 in house, Boeing built the airplane in individual parts and delegated development to more than 50 partners.

By outsourcing production, Boeing's main factory would turn into an assembly plant where pre-made parts were bolted together. More than 30% of the 787 was foreign-made, compared with 5% of the 747. When you fly on a 787, you're traveling in an aircraft that was less than 40% built by Boeing.

Outsourcing so much of the 787's manufacturing proved to be a mistake. Instead of lowering costs, it raised them. By the time the 787 took its first commercial flight in 2011, it was three years late and billions of dollars over budget.

If mid-level employees can anticipate the dangers of outsourcing, why do companies do it?

Companies outsource their operations to increase profitability.

The benefits of outsourcing are best described by Stan Shih, the CEO of a Taiwanese hardware and electronics company called Acer. [He coined a term](#) called “the smiling curve” to illustrate why certain aspects of the product creation process are more profitable than others. In the case of information technology-related manufacturing, research, development, and marketing are the most profitable areas to specialize. Fabricating the units and linking critical components is a low-margin race to the bottom. Inspired by this theory, companies like Boeing aim to specialize in high-margin activities and outsource the rest.

WHEN DOES OUTSOURCING WORK?

Outsourcing works for the electronics industry due to the low labor rate. That’s why iPhones are designed in California but made in China. Companies outsource to countries with cheap labor. Their business brings even more work, which leads to increasing hourly rates. Once the costs rise, electronic outsourcing moves to another cheap and undeveloped area, where the cycle starts over again.

But aircraft manufacturing is different. What works in high-volume industries like consumer electronics may not work in low-volume ones like aviation. Aircraft manufacturing programs are designed on a 60-year time frame — three decades for active production, followed by three more decades of support costs for hardware and software costs. Beyond that, an aircraft wing costs just a *tad* more to transport than a stone-weight iPhone.

In contrast, the 787 parts didn't seem to fit together. The wing didn't securely attach to the body of the airplane, and there was a large gap between the flight deck and the fuselage. Boeing's workers wanted the airplane to "snap together." But different parts of the aircraft, from the wings to the smoke detectors, didn't fit. Boeing paid the price:

"In the end, much of the plane's real design happened on the assembly line, and Boeing had to write off three separate mock-ups that were too much like science projects to pass off as airworthy planes. In the end, the Dreamliner (another name for the 787) cost no less than \$30 billion, and probably closer to \$50 billion."

When it comes to outsourcing, aircraft engines are the exception that proves the rule. Jet engines are built by separate manufacturers due to economies of scale for manufacturers and technical expertise that does not translate to the rest of the aircraft, making it exactly the kind of product a company should outsource.

As the famous saying goes: "In theory, there's no difference between theory and practice. In practice, there is."

One Boeing engineer named L. J. Hart-Smith warned against the dangers of outsourcing in a leaked memo published in 2001. In the memo, Smith argues outsourcing should be seen as an added cost, not a cost reduction. He observed power within Boeing had shifted from ambitious scientists to slick lawyers and financiers.

Subcontractors, not Boeing, would benefit from increased outsourcing. In the case of Boeing, outsourcing threatens the survival of the company because too much outsourcing causes the profits to disappear along with the work itself. Without lots of up-front planning, the subassemblies may not fit together at assembly, which will lead to delays and increased costs.

Outsourcing is a symptom of a larger move towards cost-cutting. Like many large bureaucracies, the aircraft industry is siloed by department. Instead of taking a comprehensive look at the system, managers analyze the business under a microscope. Each slice of the organization is responsible for minimizing their own costs instead of reducing costs for the organization at-large.

Systems, though, are interconnected. An improved engineering process can reduce the cost of designing or manufacturing a product. Rather than minimizing costs in isolation, Smith advised Boeing to take a bird's-eye view of the manufacturing process. After all, one system-wide cost reduction is worth more than 20 small and isolated efficiency gains.

I fear Boeing executives were overly concerned with following standard management doctrine. Just as "nobody got fired for buying IBM," nobody got fired for outsourcing to a cheaper manufacturer. The modern economy is globalizing, and the workers within it are increasingly specialized. But Boeing took outsourcing and cost reduction too far, and the company suffered the consequences.

In the advertising industry, companies hire third-party advertisers to do the dark and dirty work of sketchy data practices. Then, when the company is blamed for malpractice, they can point their blame at that third-party firm. I wonder if outsourcing is driven by similar

motivations. To be clear, I'm not accusing Boeing of intentionally ignoring safety. But by outsourcing manufacturing to third-parties, Boeing can shift the blame to partners with lucrative outsourcing contracts and little incentive to stand up for themselves.

Boeing's troubles were evident before the 737 Max crash. The Boeing 787 project went over budget by \$12-18 billion, with delays and unexpected costs as the culprits. Executives couldn't keep up with the 787's complex manufacturing process. The aircraft contained 2.3 million parts built in 5,400 factories. Parts from those far-flung suppliers didn't fit. Entire manufacturing lines were delayed when some subcontractors missed their quotas. Some subcontractors outsourced engineering to other subcontractors, which reduced Boeing's visibility in the project. [According to one analysis](#), one major supplier didn't even have an engineering department when it won the Boeing contract.

Due to battery fires in two planes, regulators had to ground 50 787s after the aircraft started flying. Because of these delays, I didn't fly in a 787 until 2018, twelve years after I visited the Boeing factory.

Boeing's Wake-Up Call

The 737 crashes were a wake-up call for Boeing. In the name of safety, the company shouldn't let this crisis go to waste. The only thing worse than not learning from history is learning the wrong lessons from history. I worry that Boeing will respond in ways that prevent innovation and hurt the company's long-term prospects.

To its credit, the company says safety is its number one priority. My worry is the handover from this public relations crisis will prevent the company from taking the right kinds of risks. Instead of pushing the limits of speed, the company will implement the very kinds of outsourcing practices that caused this fiasco in the first place. Ultimately, the company is moving away from its engineering-led roots.

[As Matt Stoller wrote:](#)

"The net effect of the merger, and the follow-on managerial and financial choices, is that America significantly damaged its aerospace industry. Where there were two competitors — McDonnell Douglas and Boeing, now there is one. And that domestic monopoly can no longer develop good civilian aerospace products. Hundreds of people are dead, and tens of billions of dollars wasted."

In the shadow of the 737 crashes, I worry Boeing is giving more responsibility to its corporate overlords. Meaningful changes won't be made unless Boeing analyzes its crashes in the shadows of the McDonnell Douglas merger and the 2001 Smith memo which anticipated the 787 battery fires. But the company shouldn't stop there. It should drop its culture of mergers, risk-aversion, and excessive outsourcing.

By simplifying the manufacturing process, Boeing would increase safety and reliability. The company can't move quickly or pursue bold projects unless critical components are made in-house. Then, it should shift power back towards engineers with grand and optimistic visions for the future of flight. Otherwise, Boeing will not be able to recruit the most talented aerospace engineers. If Boeing wants to repair its image, it needs to become a beacon of American progress.

Right now, Boeing is eating itself alive. Unless the company makes meaningful changes to its toxic culture, it will hamper innovation and jeopardize the lives of airplane passengers.

Footnotes

¹ As a careful reader observed, “it’s disingenuous to complain about the domestic monopoly due to the global nature of aircraft purchases. It’s the equivalent of saying that Apple has a monopoly on smartphones because Samsung is based in South Korea.” With that said, Stoller’s statement could be valid for military spending because the US military buys from Boeing, not Airbus.

² There are two duopolies in the aircraft industry: one in the market for large jets, and another in the market for small jets. Embraer and Bombardier make the smaller jets.

³ I enjoyed this [description](#) of the MCAS system from William Langewiesche: The MCAS system “provided repetitive, 10-second bursts of nose-down trim, that it could be held at bay through vigorous use of the control yoke thumb switches to counter-trim, that it would not activate if the flaps were down or the autopilot was on, that it could be deactivated by shutting off the electric trim through use of the now-famous cutout switches on the center pedestal and that afterward the airplane could be trimmed using the manual trim wheel.”

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LINKS TO THIS ESSAY

Annual Review: 2019

The New Year is a time to stop and slow down. It’s a time to reflect on the previous year and plan for the upcoming one. Every holiday season, I reserve time to conduct an Annual Review.

News in the Age of Abundance

Both cereal and the daily news began as well-intentioned efforts to improve American lives. But just as cereal turned into sugar for the body, news turned into sugar for the mind.

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