# Air and Space this Week

## Item of the Week

# *Two Important Launches, Twenty Years Apart*

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*Manned Spaceflight began on **April 12, 1961**, sixty years ago, with the launch of Yuri Gagarin aboard* Vostok 1*. His orbital flight shocked the U.S., spurring a rapid increase in the quality and uniformity of STEM education efforts. Over the next two decades, both the USSR and the USA made major strides in putting astronauts/cosmonauts into Space. The USA won the "Race to the Moon," and both countries were building Space stations. Another big step came **twenty years to the day** from Gagarin's flight, with the USA's launch of the US Space Shuttle.*

**Yuri Gagarin on *Vostok 1***

Cosmonaut Yuri Gagarin became the first Human in Space (and the first to orbit the Earth) on April 12, 1961, sixty years ago. His flight was a shock to the US, already reeling from getting between in launching an orbital satellite a few years earlier. The two events had a profound effect on US policy and educational system. The US would respond less than a month later, with Alan Shepard's *Mercury-Redstone 3* flight. It was later, and only sub-orbital, making the US a visible second-best in the Space Race, and, therefore, in the "hearts and minds of the world."

Yuri Alexseyevich Gagarin was born on a collective farm near Smolensk, USSR, on March 9, 1934. After his initial education, he worked in a steel mill at first, and had a passion for playing goal for the local hockey team. But he wanted to be a pilot, so he joined the Soviet Air Force, learned to fly, and was commissioned in November, 1957. He had served two years when he was inspired by the *Luna 3* mission to apply to be a cosmonaut, and he was named to the first group of 20 cosmonaut candidates in late 1959.

The USSR cosmonaut selection criteria were similar to those used to select the first seven astronauts for the US Mercury program, who were announced to the public on April 9, 1959. Cosmonaut candidates had to be pilots, between the age of 25 and 30, and they faced a size constraint, as did their Mercury counterparts. Cosmonauts had to be 5'7" or shorter and weigh 159 pounds or less. Gagarin was 5'2" tall.

The 20 faced a very difficult training regimen, one involving vigorous exercise and dozens of parachute jumps. One of the other selection tactics involved each candidate to name who beside themselves they would like to fly with. Seventeen of the 20 named Gagarin.

The upcoming Vostok program required the list of 20 be pared to only six. Gagarin and Gherman Titov (who would become the second person to orbit the Earth) were two of them.

Two of the originals were injured in subsequent training, and replaced by two from the 20 not initially selected.

The training for the six was the toughest yet, and it included a LOT of medical, psychological, and physical testing, just like NASA was doing with the Mercury 7.

*Vostok 1* was his first and only flight, after which he was awarded the Hero of the Soviet Union medal (equivalent to the US Congressional Medal of Honor). His home village was renamed Gagarin in his honor, and would be elected to the lower chamber, then the upper, of the Supreme Soviet.

Gagarin worked at Star City on design concepts for a ***re-usable spacecraft (!)*** for about two years following his flight.

By 1965, Gagarin had not flown as pilot for about five years, in part because he was too important to be exposed to such risks. His cosmonaut training had initially interrupted his higher education and completion of aviation flight school. He finished up both and was beginning to re-qualify as a military pilot.

Gagarin was also still a cosmonaut, and he was in the running to be selected pilot for the first of the next Russian mission series, Soyuz. However, Vladimir Komarov, not Gagarin, was selected for the ill-fated *Soyuz 1* mission. The early Soyuz spacecraft had abundant defects, many of which that were known, but not corrected by the time of Komarov's launch. Komarov was launched knowing he would likely not survive the mission. He didn't.

Gagarin was pulled from any further spaceflight operations after Komarov's death, but he was allowed to continue has jet pilot training.

He was piloting a MiG-15 with an instructor pilot on March 27, 1968. For reasons that remain controversial to this day, his plane crashed, killing both of them instantly. The intense secrecy surrounding the crash, of course, generated even more public attention and inquiry. Three separate (and sometimes competing) investigation boards were convened. Their reports rejected a number of the (conspiracy) hypotheses, concluding that either bird strikes or a sudden maneuver caused by turbulence or avoidance of another aircraft was responsible.

A member of one of the investigations later opined that a cockpit vent was the culprit, allowing the pressurized air to escape, causing Gagarin and instructor to suffer oxygen deprivation, akin to the problem that crashed golfer Payne Stewart's Learjet years later.

Famed cosmonaut Alexei Leonov, the first person to "walk in Space," and would later command the USSR side of the *Apollo-Soyuz Test Project*, was also on one of the investigations. He believed that a combination of bad weather and a near-collision with another aircraft was the cause of Gagarin's loss. He had been in the area on the fateful day, and had heard two distant booms at the time of the crash. This led him to believe that the first was a sonic boom, and the second was the sound of Gagarin's plane hitting the ground. He found out years later that a supersonic test flight had been scheduled at the same place and time of Gagarin's flight, and that the test pilot had flown much lower to the ground than he should have. It's highly likely

that the turbulence of his passage threw the lighter MiG-15 into a flat spiral, too low to the ground for Gagarin to recover.

Just over eight years after Gagarin's flight, astronauts walked on the Moon. What a tour de force of technological advancement!

One of Gagarin's post-flight assignments was to develop mission concepts for a reusable spacecraft. It was very wasteful to use a giant rocket only once to launch a relatively-small payload. What if a reusable launching system could be developed?

Well, the Russians didn't come up with a good solution. But the Americans did…

**Space Shuttle**

Rocket scientists discovered very early on that lifting heavy loads to LEO and beyond took a multi-stage rocket. If you look at a large rocket, say the Saturn V, almost the entire thing is the system to get a relatively-tiny payload to Space. Enormous engines, fuel tanks, and supporting structures and equipment are used once, and then discarded. It works, but at an enormous cost that cannot be substantively reduced as long as the multi-stage system is used.

Years ago, engineers began working on the concept of a launch vehicle more like a Space plane, where most, if not all, of the vehicle can be used over and over. The engineering required is formidable, and there is no way to avoid having to use a large fuel tank that would detach in flight, but several designs emerged.

Alas, it was Nazi Germany rocket scientists that came up with the first feasible plan, ***Silbervogel*** ("silver bird"). The idea was to have a supersonic bomber able to be launched from a base in Germany, bomb New York or Washington, then land on a Japan-held Pacific island base. The craft would be launched with a large rocket booster, and would use its wings to "skip" on the upper atmosphere. Good thing they didn't build a working prototype; they had mis-calculated the skin friction heating their Silver Bird would have experienced, before it melted.

A few of the engineers who had cooked up the rocket plane concept came to the US after WWII as part of "Operation Paperclip." Two modified their original idea for Bell Aircraft for use as a long-range bomber. Additional design and test work proceeded in the late 1950s.

Then Sputnik happened. The USAF Air Research and Development Command immediately consolidated all hypersonic bomber research into on program. Bell and Boeing competed for the new vehicle, which would come in different variants, designed for specific missions. Boeing was chosen to be the prime contractor for a reusable Space plane that had been dubbed the X-20 DynaSoar (for "dynamic soaring"). [Sheesh, a few weeks ago, I busted on Boeing's PR folks for coming up with the name 737 MAX NG (No Good). Their parents must have worked for Boeing, too; was there a Congressperson anywhere who would vote to financially support a large-budget ***dinosaur***?]

Cold War military budgets were seldom constrained by PR, however, and the basic design of the DynaSoar was taking shape by mid-1960. The new Titan III missile would be its launch vehicle.

The DynaSoar would be able to conduct reconnaissance, strategic bombing, and anti-satellite warfare.

The program got far enough along to recruit and train a cadre of DynaSoar pilots. Seven were chosen; Neil Armstrong was one of them.

The program slowed in 1962. The Titan III experienced delays in its development, and its Titan precursors were too small to launch the five-ton X-20. Worse, there was some political pushback. Some regarded a crewed Air Force rocket plane as encroaching on NASA's role as the Nation's manned Space program. The real killer was that DynaSoar was a solution without a clear problem. And it was very expensive, and would not come on line until the second half of the 1960s. So, for those reasons, the DynaSoar became a dinosaur on December 10, 1963.

But DynaSoar was not completely dead yet. Its successor was the **Manned Orbiting Laboratory**. Think of the technology that prevailed in 1963. The transistor radio, almost as big as your shoe, was the latest in communication technology. Photography meant film, not CCDs. Integrated circuits – ha! A Space-based reconnaissance capability in those days meant Human-tended, hence, the MOL. This time, McDonnell-Douglas got the prime contract, and the MOL would be a modified version of their successful Gemini capsule (think of it as a modified Gemini with a Service Module attached).

The rapid pace of technological advances in the 1960s, and having to compete with the Vietnam War (and NASA) for Federal dollars, killed the MOL. Seven of the astronauts that had been hired to fly the MOL ended up as Space Shuttle pilots later (including Bob Crippen and Gordon Fullerton), and some of the equipment designed for MOL were used on other rockets, including the solid-rocket boosters MOL would have required (they evolved into the Space Shuttle's SRBs).

**The Space Shuttle**

NASA's enormous success with the Apollo Moon landing program was the culmination of a carefully-designed and management of a large-scale technology development program. But after you have "reached the Moon," what was the next big thing to pursue? Many wanted to keep the pedal down and head for Mars with the same level of support, but that was not politically feasible (for example, two billion people watched Neil's small step, but by the scientifically-interesting Apollo missions a few months later, the networks wouldn't even preempt the soaps to show astronauts on the Moon!).

So what's a Space Agency to do?

The good news was that access to Low Earth Orbit was becoming a very important, and lucrative, commodity. But the costs of access using non-reusable rockets was a barrier. If the cost per pound to orbit could be slashed, the Space utilization industry would boom. Tech development and transfer to the private sector was still, as always, NASA's bread-and-butter.

NASA had an outstanding team on board, long in experience capped with the Apollo successes. Some sort of meaningful project was needed to keep the team intact. The reasons that led to thinking about the DynaSoar and the MOL were still in play, with some changes due to

technological advancement. Why not build a real Space Station, and a Space Shuttle that would support its construction (and carry a lot of payloads (emphasis on the "pay") to boot)?

President Nixon was a Space supporter, and he came down in favor of the Space Shuttle, announcing his decision to go forward on January 5, 1972 (just before the end of Apollo):

"I have decided today that the United States should proceed at once with the development of an entirely new type of space transportation system designed to help transform the space frontier of the 1970's into familiar territory, easily accessible for human endeavor in the 1980's and '90's.

"This system will center on a space vehicle that can shuttle repeatedly from Earth to orbit and back. It will revolutionize transportation into near space, by routinizing it. It will take the astronomical costs out of astronautics. In short, it will go a long way toward delivering the rich benefits of practical space utilization and the valuable spinoffs from space efforts into the daily lives of Americans and all people."

A lot of new technology would need to be adapted from other programs and/or created outright in order to make a re-usable Space plane possible. Two areas in particular required attention: making a cargo-carrying rocket reenter the atmosphere and land like an airplane, and the creation of non-ablative heat shielding.

NASA realized, during the shuttle design process, that the Shuttle would have to be transported from place to place on Earth, so they planned for a B747 with special adaptions that could carry a Shuttle piggy-back. Such a capability would also facilitate flight tests of the aerodynamics of the Shuttle; the 747 could carry aloft a Shuttle model and release it for realistic testing. It was built in the Constitution's bicentennial year, so NASA intended to name the test vehicle *Constitution*. However, *Star Trek* fans intervened with a massive letter-writing campaign, and the Shuttle test vehicle became the *Enterprise*. [Frankly, I'm surprised that the Trekkers didn't campaign for the test vehicle to be named "Galileo." After all, it was a *shuttle*!] The glide tests went OK, and the *Enterprise*, mission accomplished, was sent to the National Air and Space Museum.

The heat shielding issue was also a big problem. The shield had to be readily re-usable, durable enough to withstand multiple launches and re-entries, and not be too heavy. It was easy to meet one requirement, even two, but all three in one material was difficult. The solution was to line the Shuttle with special fused silica tiles. The materials they tested had interesting thermal properties. The stuff did not transfer heat well at all. You could handle it hot, because it couldn't transfer heat fast enough to your hand to hurt it. We used scraps of the test stuff in our lab as a heat shield for brazing and soldering.

Sheathing the Shuttle with tiles was a big task. Over 24,000 separate individually-numbered tiles were required, each specially made. It was a simple jigsaw puzzle (the pieces were slightly different in shape, but they were numbered), but it was a huge one. Two types of tiles were used. The parts of the Shuttle that would not bear the brunt of re-entry heat were regular fused silica tiles, good against temperatures up to 1200 °F. The underside of the Shuttle, and

the leading edges of the wings, where heating would be highest, received an additional coating of black glass, allowing them to resist temperatures up to 2300 °F; they were stronger than the white tiles, too.

The tiles were very heat resistant, but they were brittle, too, and required careful handling during installation. Once the Shuttle program was fully underway, a few dozen tiles would be damaged and have to be painstakingly replaced. There was no provision to examine the Shuttle while on orbit, apart from a difficult EVA, and there was no way to repair or replace a damaged tile until the mission was over. The problems with the tiles and other factors substantially delayed the first launch of the Shuttle.

There were some other engineering constraints that affected the design. The Shuttle, after all, was a "truck to Space," intended to launch large satellites and deliver to LEO all of the building materials required for the *International Space Station*. Its main engines were very reliable, but the Shuttle was caught in a fuel/tankage viscous cycle. Why carry launch-sized engines all the way to LEO and back instead of more payload? The Shuttle did need substantial engines for orbit changes and re-entry, but they needed way more fuel than the Shuttle could carry, and still wouldn't be enough to carry it all to LEO. The solution was a variation on the staged rocket tactic. The Shuttle would be attached to giant fuel tank, which would be jettisoned after its fuel was expended. The Shuttle with external tank was still much too heavy to make LEO, even without cargo. The solution was to attach two solid rocket boosters, an updated version of those on earlier ballistic missiles. They would have the necessary oomph, but they had the disadvantage of not wanting to shut off after they are lit. They also were too large to be manufactured in one piece; they were built in sections (think gigantic Tootsie Roll…). NASA hoped to recover the spent solid rocket boosters and refurbish them for use on a subsequent Shuttle flight. They did not expect to recover the large fuel tank.

Finally, all the building and testing was finished. The Space Shuttle *Columbia* was ready for launch. Her crew had been selected three years earlier. Veteran astronaut and Chief of the Astronaut Office, John Young, named himself the mission commander, and rookie astronaut (and former MOL guy) Robert Crippen would be the Pilot. Young had flown on the *Gemini 3* spacecraft with Gus Grissom (the first crewed Gemini mission), commanded *Gemini 10*, served as the Command Module Pilot for *Apollo 10*, and commanded the *Apollo 16* mission, walking on the Moon with Charles Duke. He also would fly another time in the Shuttle. Crippen would end up commanding three Shuttle missions and serving stints as Director of the Space Shuttle Program and Director of the Kennedy Space Center.

The Shuttle missions needed a naming system, since any given Shuttle would make many flights. NASA called the Shuttle and its enabling technology "the Space Transportation System," or STS for short. Each flight, almost always, would be named sequentially, so STS-1 would be the first. Some wanted the first mission to not go to orbit, but would rather serve as a live test of the Return to Launch Site abort procedure. Young was strongly opposed, saying "Let's not practice Russian roulette, because you may have a loaded gun there," and listened to, so STS-1 was "go for orbit."

Launch date was scheduled for April 10, 1981. A few technical glitches caused a two-day delay. STS-1 would launch on April 12, ***twenty years to the day after Gagarin's flight***. Not by design, perhaps, but I think a much more appropriate coincidence.

*Columbia* carried no cargo, just equipment to monitor all aspects of the Shuttle's systems. This was a test flight on a grand scale. Young and Crippen's busy schedule comprised 113 flight test objectives, and they met every one of them. The *Columbia* was not only Space-worthy, she performed very well. Only one problem raised concern….

The STS-1 crew opened the cargo bay doors not long after attaining LEO. This had to be done to manage heat generated by the launch, and it also served as the test of the door operating equipment. The doors worked great, but as the astronauts looked out through the cargo bay, they noticed that a few of the heat-resistant tiles on the fairing around the Orbiter Maneuvering System thrusters were damaged. Consternation aloft and below! There wasn't much they could do about it; at least the damage was on a part of the Shuttle where re-entry heat wouldn't be too high, and it didn't look too bad.

I was a grad student stationed at NASA Ames Research Center at this time. I missed the launch, but the landing would take place on April 14, a weekday, during business hours. This was 1981 remember, so audio-visual technology meant a big heavy CRT television. The Ames cafeteria mounted them all over the place. Everyone on base was there, we were packed in like sardines. I'm sure the Fire Marshall would not have been pleased. We didn't care; the atmosphere was electric, and we were a witness to history. The camera picked up the *Columbia* as it approached the huge runway at Edwards. Young greased the huge craft to the runway perfectly, using the soon-to-be-familiar steep descent and rapid flare. The cafeteria had gone dead silent when the Shuttle came on the screen, and nobody uttered a sound as the Shuttle's main landing gear touched down. The nose slowly dropped, and when the nose wheel touched the runway, the cafeteria erupted in deafening cheers. People were jumping up and down on tables and chairs, pounding each other on the back, in a paroxysm of pure joy.

The Space Shuttles flew a total of 133 successful missions. Some were classified DOD missions (in keeping with the ideas that led to planning for the MOL). Others launched important Solar System probes (*e.g.* the Hubble Space Telescope and its maintenance missions, the *Compton Gammy Ray Observatory*, the *Long-Duration Exposure Facility*, *Chandra X-ray Observatory*, six TDRS communications satellites, *Magellan* (Venus orbiter), *Galileo* (Jupiter orbiter), and *Ulysses* (solar mission), and others launched commercial satellites. Many experiments in biomedicine, physics, metallurgy, etc. were conducted in laboratory modules carried on some missions. And Shuttles successfully carried to LEO all of the components of the *International Space Station*.

Unfortunately, there were 135 Shuttle launches. But only 133 safe landings.

STS-51-L, the *Challenger*, was scheduled to launch on January 28, 1988. It carried a Tracking and Data Relay Satellite (TDRS) and a booster that would carry it to a higher orbit than the Shuttle could attain, and a satellite that would observe Halley's Comet. It had a crew of seven, including the first Teacher-in-Space, Christa McAuliffe. The networks had not carried a launch live in years, but for this particular mission, the public interest in a "civilian" flying in a Shuttle,

and giving a class lesson from orbit, meant that the launch was widely broadcast. Students were released from their classroom across the county, and went to an assembly where they could watch the launch.

We all know what happened. The external fuel tank exploded 73 seconds after launch, and everybody got to see it live. The joint between two of the solid rocket booster sections of one of the SRBs, sealed by a rubber O-ring, leaked, with a jet of flame on the side facing the external tank. The tank blew, and all seven aboard *Columbia* died. The O-ring failed because the Shuttle had been launched in cold weather, which made the O-ring material stiff and less effective.

NASA would not try to launch another teacher into Space (astronauts do give lessons from orbit, however). The Shuttle fleet was grounded and an intensive investigation took place as to the cause of the accident. Noted physicist Richard Feynman gave a memorable demonstration of the effect of cold on O-ring material by publicly dunking it in his glass of ice water during the hearings, and showing that the once-pliable ring went stiff.

Many changes were made in the SRBs as a consequence of the investigation findings, and flight operations resumed 32 months after the disaster. Subsequent missions went well, until…

STS-107, *Columbia*, was launched on January 16, 2003. The fuel in the Shuttle external tank is hydrogen, cooled to a liquid (-423 °F!) so that more could be carried, as well as liquid oxygen as the fuel's oxidizer. The tank had a thick layer of a foam-like insulation to help keep the fuel cold. Some in NASA had worried that chunks of insulation dislodged during launch could damage tiles on the leading edges or bottom of the Shuttle orbiter, but that hadn't been a major problem on previous missions. But this time, high-speed video taken during launch showed a rather large piece of insulation strike the leading edge of the left wing, and burst into dust. Did it cause damage? And if so, what should/could be done about it?

The seven-person crew was very busy over the 16-day mission, performing a number of experiments in a variety of fields. Meanwhile, NASA continued to worry about the potential damage suffered by *Columbia*. DOD offered to direct a spy satellite upward, rather than downward, in an attempt to ascertain damage, but were rebuffed. Landing was scheduled for February 1.

The tiles on the leading edge of the left wing ***had*** been badly damaged. Hot gases during re-entry invaded the wing, causing a cascade of warnings (or lack thereof as the various sensors were fried), and the Shuttle became uncontrollable. It broke up over Texas, killing all aboard.

The failure telemetry made it pretty clear what had happened. The Shuttle fleet was again grounded until a method of being able to examine the Shuttle while in orbit to ascertain any damage incurred during launch, and a means to make minor repairs to any dinged tiles discovered. The Shuttle external tank and its insulation were re-designed, and, after a three-year delay, the Shuttles flew again.

The remaining Shuttles were retired for good in July, 2011. After that, American crew transiting to the *ISS* hitched a ride on the Russian old-but-reliable Soyuz. We are just now getting the capability of sending folks to-from the *ISS* via commercial launch vehicles.

When the Shuttle were retired from service, NASM got first dibs on the senior Shuttle present, *Discovery*. After a lot of political wrangling, *Endeavor* went to LA, *Atlantis* to KSC, and the *Enterprise* went to the Intrepid Museum in New York. Getting the Shuttles to their final home was difficult, especially for *Endeavor* and *Enterprise*. When the *Discovery* was delivered to NASM's Udvar-Hazy Center, adjacent to Dulles Airport, NASM had both *Enterprise* and *Discovery* for a brief period. *Enterprise* was then loaded on the 747 and off she flew to New York. [Getting *Enterprise* to JFK Airport was easy, but getting it up to the *Intrepid* was not. I was in on a meeting to discuss options. After there was a lot of discussion without a good solution, I blurted out, "Well, Captain Sully isn't doing anything lately. Let's get *Intrepid*'s arresting gear out of storage, beef it up, hang a super-duty tailhook on *Enterprise*, and let Sully dead-stick it to *Intrepid*'s deck. There was a three-second silence before the laughing began….]

**Yuri's Night**

The co-incidence in dates between Gagarin's flight and the STS-1 launch has not gone unnoticed; it is the motivation behind "Yuri's Night," a "World Space Party" that celebrates both anniversaries. The first of these annual events was held on April 12, 2001, twenty years ago. Not all of the festivities will occur on April 12, but they will be conducted sometime this week. This year, the celebration will be live-streamed on April 10. In Colorado Springs, an event will be held at the U.S. Space Foundations Discovery Center on the evening of April 17. What a nice legacy for both Yuri Gagarin, and all those who made the US Shuttle program so successful!

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https://www.history.nasa.gov/shuttlehistory.html

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https://www.nasa.gov/centers/marshall/news/background/facts/SpinoffsFromTheShuttleFS.html

Space Shuttle *Enterprise*:
https://science.ksc.nasa.gov/shuttle/resources/orbiters/enterprise.html

*Enterprise* and *Discovery* together at NASM: https://www.si.edu/newsdesk/photos/space-shuttles-enterprise-and-discovery-meet-nose-nose

*Enterprise* at the Intrepid Museum: https://www.intrepidmuseum.org/Space_Shuttle_Pavilion

More about the *Enterprise*: https://www.nasa.gov/subject/3440/shuttle-enterprise

Original STS-1 NASA site: https://www.nasa.gov/mission_pages/shuttle/sts1/index.html

NASA History of STS-1: https://www.history.nasa.gov/sts1

STS-1 Pictures: https://www.space.com/11345-photos-nasa-space-shuttle-1st-flight-sts1.html

NASA Mourns John Young: https://www.nasa.gov/astronautprofiles/young

NASA bio for Robert Crippen:
https://www.nasa.gov/missions/highlights/webcasts/history/bcrippen-bio.html

Space Shuttle Tiles:

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Shuttles on Display Today

***Discovery*** is at the National Air and Space Museum's Udvar-Hazy Center:
https://airandspace.si.edu/explore-and-learn/topics/discovery

***Atlantis*** is on display at the Kennedy Space Center:
https://www.kennedyspacecenter.com/explore-attractions/shuttle-a-ship-like-no-other/featured-attraction/space-shuttle-atlantis

***Endeavor*** is on display at the California Science Center in Los Angeles:
https://californiasciencecenter.org/exhibits/endeavour-experience/space-shuttle-endeavour

**Yuri's Night 2021** (April 17): https://yurisnight.net; https://yurisnight.net/livestream

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