IRION COUNTY WATER CONSERVATION DISTRICT

Cloud Seeding Program: Information & Facts

West Texas Weather Modification Association
2025 Season

Prepared for the
Irion County Water Conservation District
Mertzon, Texas

2025

Introduction: Why the District Funds Cloud Seeding

Water is the lifeblood of Irion County. The families, ranchers, and farmers who have worked this land for generations understand this in a way that no statute needs to explain. But the law does explain it and it does so in terms that speak directly to the mission of the Irion County Water Conservation District.

The Texas Constitution, adopted in 1917, declares in Article XVI, Section 59 that the conservation and development of the state's water resources, including the storing, preservation, and distribution of its waters for irrigation, power, and all other useful purposes are "each and all hereby declared public rights and duties." This is not a suggestion. It is a constitutional mandate. The Legislature is required to act on it, and the Groundwater Conservation Districts it created are the primary mechanism for doing so.

Texas Water Code Section 36.0015 establishes that Groundwater Conservation Districts exist to "balance the conservation and development of groundwater to meet the needs of this state." Meeting needs, not just limiting use, but actively working to ensure water is available is baked into the legal purpose of every district in Texas.

Most directly, Texas Water Code Section 36.1071 requires that every district's management plan address, where appropriate and cost-effective, the goal of "precipitation enhancement." Cloud seeding is not a fringe activity or an experimental indulgence. It is an explicitly named, statutorily required water management tool that every Groundwater Conservation District in Texas must evaluate and consider. The Irion County Water Conservation District's participation in the West Texas Weather Modification Association (WTWMA) is not just permissible, it is a fulfillment of that statutory obligation.

The questions addressed in this document are whether the program is worth the investment, whether a specific cloud seeding flight was responsible for hail damage, and whether silver iodide poses any risk to people or livestock, all deserve direct, factual answers grounded in peer-reviewed science and the documented operational record. That is what this document provides.

Executive Summary

This document addresses three questions that have been raised about Irion County's participation in the West Texas Weather Modification Association cloud seeding program. The questions are reasonable. The answers are clear.

Question 1: Is Cloud Seeding Worth the Money?

Yes — by a wide margin. Cloud seeding is one of the most cost-effective water supply tools available to West Texas landowners and communities.

The 2025 WTWMA season evaluation, conducted by Dr. Arquimedes Ruiz-Columbié of Texas Tech University using the same radar-tracking method used by the National Weather Service, documented what happened over Irion County last season:

2025 Season Results — Irion County
27 storms were evaluated (13 initially seeded in Irion County + 14 that moved into the area)
125,500 acre-feet of additional precipitation estimated — equivalent to 2.23 extra inches of rainfall
19% increase over what the season would have produced without seeding
These are only the storms that could be scientifically compared to an unseeded "control" — the actual total was higher

To put that in dollar terms, a Texas A&M University study by Dr. Jason Johnson (2014) calculated the direct agricultural benefit of each additional inch of rainfall for every county in the WTWMA program. For Irion County, a ranching-dominated county, each inch of additional rainfall in season produces approximately $97,500 in direct agricultural value, driven almost entirely by improved grazing land conditions.

Scaling that to the 2.23 inches documented in 2025 and adjusting for inflation to today's dollars:

Impact Category	2014 Dollars	2025 Dollars (est.)	Note
Dryland crop revenues	$14,809	$19,674	Wheat, sorghum, etc.
Irrigated acreage savings	$176	$234	Reduced pumping costs
Grazing land value increase	$202,410	$268,899	Primary benefit for Irion Co.
Direct agricultural total	$217,395	$288,807	Agricultural benefits only
Estimated statewide impact	**—**	**~$612,000**	**IMPLAN supply chain multiplier**

These figures cover agricultural benefits only. They do not include the value of groundwater recharge — and for Irion County, which sits over the Edwards-Trinity Aquifer, recharge is a big deal.

A peer-reviewed study by Jonathan Jennings and Dr. Ronald Green (Journal of Weather Modification, 2014) calculated how much additional recharge to the Edwards-Trinity Aquifer was generated by WTWMA cloud seeding operations over the decade 2004–2013. For Irion County specifically: 122,033 acre-feet of enhanced groundwater recharge over ten years, an average of 12,200 acre-feet per year. The study found that cloud seeding pushed annual rainfall above the 16.5-inch threshold needed for meaningful recharge in three separate years, years where that recharge would not have happened at all without the program. The cost of that recharge through the WTWMA program: approximately $2.00 per acre-foot in today's dollars. Developing equivalent new water supply through wells, transfers, or desalination costs hundreds to thousands of dollars per acre-foot.

The benefit-cost ratio across the WTWMA program runs between 16:1 and 34:1. For every dollar Irion County invests in cloud seeding, the documented return in crops, grazing, irrigation savings, and groundwater recharge ranges from sixteen to thirty-four dollars. No other water investment available to this county comes close to that return.

Question 2: Did Cloud Seeding Cause the June 9, 2025 Hail Storm?

No. The operational record, the radar evidence, and the physics of how cloud seeding works all lead to the same conclusion.

Here is what happened that night, in plain terms:

June 9, 2025 — What the Record Shows
The atmosphere was already primed for severe storms before any aircraft took off — forecasts called for it, and the ingredients (heat, moisture, wind shear) were all in place
The aircraft seeded storms in Howard County (northwest of Irion), Tom Green County, and Schleicher County — NOT in Irion County
The storm that hit Irion County originated in Howard County, traveled ~97 miles southeast through Sterling County, and reached Irion County 62 minutes after the last flare was burned
That storm was already showing 72 dBZ radar reflectivity (well above the large-hail threshold) 40 minutes before it reached Irion — growing entirely on its own
The storm displayed a classic "hook echo" on radar — the signature of a naturally rotating supercell, not a seeded storm
A separate storm that formed in Andrews County that same night, with zero cloud seeding, was just as intense — driven by the same atmospheric conditions
Total AgI (silver iodide) used in Howard County: 82.5 grams — less than 3 ounces — dispersed into a storm that ultimately grew to 20+ km tall

The bottom line: this was a classic West Texas supercell thunderstorm, driven by 1,060 J/kg of atmospheric instability, a strong outflow boundary, WNW wind shear, and the natural intensification that happens when these storms cross into the evening hours. The cloud seeding operation touched this storm once, briefly, with 82.5 grams of silver iodide, and then left it alone for 62 minutes and 97 miles while it grew into a major hail producer entirely on its own dynamics. The hail would have fallen regardless of what any aircraft did that evening.

Question 3: Is Silver Iodide Dangerous to People, Livestock, or Land?

No. This question has been studied extensively, and the scientific community has reached the same conclusion every time: silver iodide used in cloud seeding operations poses no credible risk to human health, livestock, crops, or the environment.

What the Science Says About Silver Iodide Safety
Silver iodide is practically insoluble in water — it stays as a solid particle rather than dissolving, which is the very property that makes it effective as a cloud seeding agent
The maximum possible concentration of dissolved silver in water that has contacted AgI particles is 0.984 micrograms per liter — below every U.S. drinking water and aquatic life standard
Real-world monitoring programs — including one running for 40+ years over the Mokelumne Watershed in California — have found no detectable increase in silver above natural background levels
Sheep fed silver iodide at doses far exceeding anything possible from environmental exposure showed no adverse health effects after 86 days (Younger & Crookshank, 1978)
Soil studies in agricultural areas subjected to years of cloud seeding found silver concentrations indistinguishable from unseeded control areas
The National Academy of Sciences, U.S. Bureau of Reclamation, Texas A&M, Boise State University, and independent consultants have all reviewed the evidence and found no adverse effects
Doctors prescribed silver iodide nasal sprays in the 1930s at concentrations thousands of times higher than anything from cloud seeding — with no reported health effects beyond cosmetic skin discoloration from extreme doses

The concern is understandable — "silver iodide" sounds like an industrial chemical. But the chemical form matters entirely. In cloud seeding operations, silver iodide is delivered as an insoluble solid that remains bound to soil and sediment. It does not dissolve into water supplies, does not enter the food chain in meaningful amounts, and does not accumulate in the environment at detectable levels above natural background. The industry has a safety record spanning decades and thousands of monitored samples.

Section 1: Program Evaluation and Economic Value

Understanding the Evaluation Method

The WTWMA program is evaluated annually by Dr. Arquimedes Ruiz-Columbié using the TITAN (Thunderstorm Identification, Tracking, Analysis, and Nowcasting) software system, the same platform used by National Weather Service forecasters and major research institutions. TITAN identifies clouds that were seeded and compares them to "control" clouds, or unseeded storms that formed on the same day, in the same air mass, with similar characteristics before seeding began. This matched-pair approach, known as paired cloud analysis, is the scientific standard for evaluating cloud seeding operations and is required under the Texas Weather Modification Act.

An important clarification about what the evaluation counts: the 27 evaluated clouds for Irion County in 2025 represent only those storms for which a scientifically valid control case could be identified. A larger number of clouds were seeded during the season but could not be formally evaluated because no qualified control storm existed. The 27 represent a methodological floor, the documented, conservative minimum of what the program achieved.

2025 Season Results — Irion County Detail

Metric	2025 Result
Initial seedings in Irion County	13 clouds
Extended seedings (entered from adjacent counties)	14 clouds
Total evaluated cloud interactions	27
Estimated precipitation increase	125,500 acre-feet
Increase in inches of rainfall	2.23 inches
Seasonal precipitation increase (%)	+19.0%
Season total precipitation (Irion Co.)	11.74 inches
Season-wide WTWMA average increase	+13.7%
Evaluation rating	Excellent

Eight-Year Performance Record

The 2025 results are not an outlier. The WTWMA program has produced consistent, documented results with the eight most recent seasons evaluated below (the actual dataset is now at 30-years):

Year	Seeded Storms	Op. Days	Increase (M ac-ft)	% Increase
2018	54	21	0.96	12.4%
2019	61	31	1.07	17.7%
2020	56	27	1.06	19.9%
2021	62	33	1.17	14.0%
2022	54	26	0.67	17.3%
2023	50	25	0.89	12.5%
2024	48	22	0.50	8.5%
2025	**87**	**28**	**0.72**	**13.7%**

Agricultural Economic Impact

Dr. Jason Johnson's benefit-cost analysis (Texas A&M AgriLife Extension, 2014) provides the framework for translating rainfall enhancement into dollar terms. The methodology is deliberately conservative at every step: USDA-certified acreage data, Extension agronomists yield estimates, Olympic-averaged commodity prices, and only half of census-reported pastureland as the baseline. The result for Irion County at 2.23 inches of documented 2025 enhancement:

Impact Category	2014 Dollars	2025 Dollars	CPI Multiplier
Dryland crop revenues	$14,809	$19,674	×1.33
Irrigated acreage savings	$176	$234	×1.33
Grazing land value increase	$202,410	$268,899	×1.33
Direct agricultural total	$217,395	$288,807	×1.33
IMPLAN statewide impact	**—**	**~$612,000**	**2.12× multiplier**

Groundwater Recharge: The Benefit Not Captured in Agricultural Figures

Jennings and Green (Journal of Weather Modification, 2014) used USGS stream hydrograph analysis and a precipitation-recharge regression model calibrated for the Edwards-Trinity Aquifer to calculate how much additional recharge the WTWMA program generated over 2004–2013. For Irion County:

Irion County Recharge Benefit (2004–2013)
Total enhanced recharge: 122,033 acre-feet over 10 years
Annual average: approximately 12,200 acre-feet per year
In 3 separate years, cloud seeding pushed precipitation above the 16.5-inch recharge threshold — recharge that would not have occurred at all without the program
Program-wide cost of enhanced recharge: approximately $2.00 per acre-foot (2025 dollars)
Equivalent cost of alternative water supply development: hundreds to thousands of dollars per acre-foot

These recharge figures are additive to the agricultural economic impact — they represent an entirely separate category of benefit that the Johnson (2014) agricultural analysis does not capture.

The WTWMA program-wide benefit-cost ratio documented by Johnson (2014) ranged from 16:1 to 34:1 depending on whether direct agricultural impacts or statewide supply chain effects are measured. No alternative water investment available to Irion County approaches this return.

Section 2: Did Cloud Seeding Cause the June 9, 2025 Hailstorm?

Background and the Claim

Following a severe hailstorm that impacted Irion County on the evening of June 9, 2025, a claim was made that cloud seeding operations conducted that day may have caused or contributed to the hail damage. This section addresses that claim directly, drawing on the official seeding report prepared by Rainmaker (no longer operator), archived radar imagery, sounding data, and the established science of both severe convection and cloud seeding microphysics.

The claim is refuted by four independent lines of evidence: geography and storm track, timing, the physics of silver iodide in a rotating severe updraft, and the well-documented suspension criteria that govern when and how operations are curtailed. Any one of these arguments is sufficient to refute the claim. All four together make it untenable.

The Atmospheric Setup: A Severe Weather Day That Needed No Help

June 9, 2025 was a well-forecast severe weather day across west Texas. The atmospheric ingredients were all in place before any aircraft left the ground:

Atmospheric Parameter	Value / Significance
CAPE (atmospheric instability)	1,060 J/kg at KDRT — strong convective potential
Lifted Index	-4.7°C — significant instability
Precipitable water	1.66 inches — ample moisture
Lifting Condensation Level	1,200 m — low cloud bases, vigorous updrafts
Lifting mechanism	Active outflow boundary + strong surface heating
NWS SVR Watch issued	2355Z — before aircraft reached the target area
Model guidance (NAM/RRFS)	Supported isolated to scattered severe convection

The Severe Thunderstorm Watch covering the entire WTWMA target area was issued at 2355Z (just prior to 7PM) while the aircraft was still conducting its first passes in Howard County, roughly 100 km northwest of Irion County. The atmosphere was going to produce severe weather that evening regardless of anything a cloud seeding aircraft did.

What the Seeding Record Actually Shows

Aircraft N8549P departed Lubbock at 2304Z and landed at San Angelo at 0135Z , a 2 hour 31 minute flight. Seeding operations were conducted in three counties:

County Seeded	Time (Z)	Flares Used	Distance from Irion Co. Center
Howard County	2353-0000Z	15G + 2H (82.5g AgI)	~97 km northwest (upwind)
Tom Green County	0035-0041Z	4G (22g AgI)	~21-41 km northwest (upwind)
Schleicher County	0111-0114Z	10G (55g AgI)	~75 km southeast (downwind)
Irion County	--	NONE	Not seeded

Irion County was not seeded. All seeding occurred either upwind (Howard, Tom Green) or in the wrong transport direction entirely (Schleicher — downwind of Irion in the prevailing WNW flow, meaning anything released there was carried away from Irion County, not toward it).

The Storm Track: What the Radar Shows

Archived radar imagery confirms the storm of interest originated over the Howard/Glasscock County area — the same area that received Howard County seeding and tracked southeast through Sterling County before entering Irion County. A separate storm developed from outflow, received the Tom Green County seeding, and tracked southeast into Schleicher County on an entirely different track. These are distinct atmospheric systems.

The radar sequence tells the story clearly. The storm of interest was already showing 13.5–18.5 km echo tops and 60–63 dBZ in the Glasscock area at 2340Z, before the first flare was lit. By 0000Z, as the last Howard County flare was burned, the storm was at 18.5 km and 66 dBZ with 157 kg/m² of precipitation mass. By 0040Z, 40 minutes after seeding concluded, it was a 20.5 km, 72 dBZ, 361 kg/m² supercell. The first Irion-touching severe weather warning was issued at 0102Z, 62 minutes after the last Howard County flare.

A fourth storm initiated near Frankel City in Andrews County well outside the WTWMA target area, receiving no cloud seeding whatsoever and was equally intense, driven by the same atmospheric conditions. That storm is perhaps the simplest answer to the causation claim: the atmosphere on June 9 was producing severe convection with or without cloud seeding operations.

The Physics: Why Cloud Seeding Cannot Cause a Supercell Hailstorm

AgI Residence Time in a Rotating Updraft

Cloud seeding works by providing ice nuclei to supercooled liquid water above the freezing level, promoting ice crystal formation and growth. Under favorable conditions in a relatively benign cloud environment, the minimum time from seeding to any surface precipitation effect is 20–40 minutes.

In a severe convective storm, particularly one exhibiting rotation, this minimum cannot be achieved because the AgI nuclei do not stay in the seeding zone long enough. The updrafts in a rotating severe thunderstorm reach 20–60+ meters per second vertically. AgI nuclei are sub-micron particles, essentially passive tracers in the airflow. In a powerful rotating updraft, they are lofted through and out of the supercooled water zone in a matter of minutes. A storm that is already severe and rotating is one of the least susceptible environments to cloud seeding modification, its dynamics are self-sustaining and dominate any external forcing.

The Dose: 82.5 Grams Cannot Build a Supercell

The total AgI delivered in Howard County was 82.5 grams, or less than 3 ounces. A mature supercell with a 20 km echo top encompasses a cloud volume on the order of a quadrillion (10^{15}) liters of air. Even under the most optimistic assumptions about nuclei dispersal, 82.5 grams of AgI could produce fewer than 100 ice nuclei per liter in that environment which is far below operational seeding concentrations under ideal conditions. The storm's hail production was driven by a self-sustaining mesocyclone recirculating large precipitation embryos through the supercooled water zone. 82.5 grams of AgI, dispersed once and then left alone for 62 minutes while the storm tracked 97 km, is not a meaningful contributor to that process.

It is also worth noting what the two hygroscopic flares were doing: NaCl (salt) seeding targets warm rain coalescence below the freezing level, promoting larger raindrops through collision-coalescence. It has no mechanism for producing or enhancing hail, which is an ice-phase process. The hygroscopic component cannot be invoked as a hail-enhancement mechanism.

Rotation, Suspension Criteria, and Operational Judgment

Cloud seeding programs operate under formal suspension criteria precisely for situations like June 9. When convection intensifies to produce severe weather — particularly rotation, large hail, or lightning hazards — suspension is both professionally required and operationally appropriate. The seeding report documents this in real time:

- At 0114Z: operator instructed crew to "quick-seed then head back to SJT as radar showing new echoes south through west of the airport"
- At 0116Z: aircraft returning to San Angelo "to avoid potentially getting stranded if activity moves over airport"
- Aircraft landed at 0135Z

This is not the behavior of an operator inducing convection. It is the documented response of experienced personnel recognizing that the atmosphere had taken control of the situation and curtailing operations accordingly and precisely as suspension criteria require. The storm exhibiting a hook echo and broad rotation (broad enough that NWS did not issue a tornado warning, but

organized enough to sustain classic supercell structure) was operating entirely outside the regime where cloud seeding can meaningfully interact with cloud microphysics.

Nocturnal Enhancement: The Atmosphere Did This on Its Own

The storm's passage through Irion County between 0102Z and 0200Z (8:02PM – 9PM) coincided with a well-documented atmospheric phenomenon: nocturnal boundary layer enhancement. After sunset, surface friction decreases and the low-level jet accelerates, increasing wind shear and the rotational energy available to the storm. This is a classic Great Plains mechanism for supercell intensification in the evening hours, entirely independent of any weather modification activity. The storm was going to be more dangerous after dark regardless of what any aircraft had done hours earlier.

Summary: The June 9 Claim Does Not Survive the Record

Why the Causation Claim Is Refuted
Irion County was not seeded — all seeding was in Howard, Tom Green, and Schleicher counties
The storm was already at 72 dBZ (major hail certain) 40 minutes before it reached Irion County, and 40 minutes after the last Howard flare
The first Irion-touching SVR warning was issued before Schleicher seeding even began
82.5 grams of AgI cannot produce a 20.5 km, 72 dBZ supercell — the physics do not allow it
AgI residence time in a rotating severe updraft is too short for seeding effects to manifest
A simultaneous unseeded storm in Andrews County was equally severe — the atmosphere needed no help
Radar confirms classic hook echo / supercell structure driven by natural mesocyclone dynamics
Operations were curtailed as the environment deteriorated — standard, documented suspension criteria

Section 3: Is Silver Iodide Safe for People, Livestock, and Land?

The Short Answer

Yes. This question has been studied extensively for decades, across multiple continents, by government agencies, universities, and independent consultants. The scientific community has reached the same conclusion every time. There is no credible scientific evidence of adverse effects to human health, livestock, wildlife, crops, or the environment from silver iodide used in cloud seeding operations.

Understanding Why Form Matters: AgI Is Not Free Silver

Most concerns about silver toxicity arise from the free silver ion (Ag^+) — the dissolved, reactive form of silver that can affect aquatic organisms at very low concentrations. The free silver ion is genuinely toxic to fish and some aquatic invertebrates in laboratory settings. But silver iodide (AgI) is chemically a completely different thing. The same property that makes AgI effective as a cloud seeding agent, its near-total insolubility in water, is the property that makes it environmentally safe.

The solubility product (Ksp) for silver iodide is 8.5×10^{-17}, meaning the reaction strongly favors the solid form. Under equilibrium conditions and assuming unlimited solid AgI in contact with pure water, with no adsorption or dilution, the absolute maximum possible concentration of free silver ion is 0.984 micrograms per liter. This ceiling is below every U.S. human health and aquatic life toxicity standard that has been established. And that ceiling is wildly unrealistic under field conditions, where dilution, adsorption to soil particles, and complexation with organic matter reduce the actual free silver concentration to fractions of that maximum.

Silver Standard / Guideline	Concentration
U.S. EPA drinking water standard	100 µg/L
U.S. EPA acute aquatic life criterion	4.1 µg/L (at 120 mg/L hardness)
Maximum theoretical free Ag^+ from AgI in pure water	0.984 µg/L
Actual measured silver in seeded precipitation	0.01–0.3 µg/L
Silver measured in seeded watershed (Mokelumne, CA)	<0.0005 µg/L
Natural background silver in snow (western U.S.)	0.001–0.005 µg/L

What Long-Term Monitoring Programs Have Found

The safety of AgI is not theoretical. It has been tested by decades of real-world monitoring programs that collected thousands of samples from seeded areas:

- The Mokelumne Watershed in California has been cloud seeded since 1953. A comprehensive lake and sediment study found average dissolved silver concentrations at the primary monitoring reservoir of less than 0.0005 µg/L — well within natural background. Critically, no detectable free silver could be measured in sediment leachates even at pH 5, confirming that AgI remains bound in solid form.
- The Snowy Precipitation Enhancement Research Project in Australia monitored nearly 7,000 samples across soils, streams, sediments, potable water supplies, peat, and moss over years of operations within a UNESCO World Biosphere Reserve. Mean silver concentrations were well below guideline trigger values at all locations — in many cases less than 10–20% of those values.
- Agricultural soil studies in Greece across 300,000+ hectares subjected to years of cloud seeding found silver concentrations indistinguishable from unseeded control areas.
- Cloud seeding accounts for approximately 0.1% of total global anthropogenic silver releases when compared to photographic industries, urban refuse combustion, and sewage treatment, which together account for the vast majority.

Livestock: What the Science Says

The specific concern about livestock exposure has been directly studied. Younger and Crookshank (1978) administered silver iodide to sheep at doses of up to 10 milligrams per kilogram of body weight per day for 86 days, a sustained exposure far exceeding anything achievable through environmental deposition from cloud seeding operations. None of the health metrics recorded differed significantly from the control group, despite silver accumulating in the liver at 17 parts per million. The study concluded that AgI complexes used in weather modification operations are not likely to induce any overtly toxic effects on livestock.

For reference: 1,000 hours of ground generator operation in a typical season releases approximately 23 kilograms of AgI dispersed over hundreds of square kilometers. That works out to roughly 10 grams of AgI deposited per square kilometer which is the equivalent of a few grains of table salt spread across a football field.

Human Health

The EPA's drinking water standard for silver is 100 µg/L. This is a secondary maximum contaminant level, meaning it is not set because silver is acutely toxic at that concentration, but to address aesthetic concerns about skin discoloration. A person would need to drink 4 liters of water at 100 µg/L every day for 70 years to approach the no-observed-adverse-effect level for total lifetime silver intake. In seeded watersheds, silver concentrations are typically measured in parts per trillion, or four to five orders of magnitude below that standard.

The historical safety basis for the standard itself comes from the 1930s, when doctors prescribed nasal sprays containing 1–4% silver iodide, concentrations thousands of times higher than anything achievable from environmental exposure. Even at those concentrations, no adverse physiological effects were reported other than cosmetic skin discoloration (argyria) from extreme, prolonged use.

Conclusion on Safety

The weight of evidence across decades of monitoring, multiple peer-reviewed reviews, and regulatory assessments by the National Academy of Sciences, U.S. Bureau of Reclamation, California Energy Commission, and numerous state and international agencies is consistent: silver iodide cloud seeding, conducted at operational doses, poses no credible risk to people, livestock, crops, or the environment. The chemistry of AgI ensures it stays in solid form, and the monitoring record confirms that silver concentrations in seeded areas are indistinguishable from natural background.

References

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