



ONE EYE, ONE BRAIN, MANY HANDS

WHY A SURVEYOR, A CCR DECISION CORE AND A TEAM OF ASSISTANTS IS THE RIGHT ARCHITECTURE FOR WILDFIRE AND SAR

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How the observation platform, the CCR decision core and the assistant aircraft (drones, then optionally manned helicopters) coordinate; what each layer contributes that the others cannot; what the alternatives are and where they fail; the doctrine the architecture descends from; and the research and programme evidence, through November 2026, that a high observer plus a small number of capable actors under a reviewable decision layer outperforms both a single big aircraft and a flat swarm.

01

The shape of the problem

A wildfire and a wilderness search share four properties that decide what architecture can work. They are partially observed: nobody sees the whole fire or the whole search area, and what is seen is minutes old. They are dynamic: the fire moves at metres per minute, the lost person moves too, and the wind changes everything. They are multi-asset: the effect comes from several aircraft working the same problem, which means allocation and deconfliction. And they are accountable: a named human is responsible for every drop and every search decision, and will be asked afterwards why.

Those four properties map onto three jobs. Someone must see, continuously and from above; someone must decide, allocating assets against a moving picture under a human's authority; and several someones must act, with mass and precision. The architecture in this paper assigns each job to the layer best built for it.

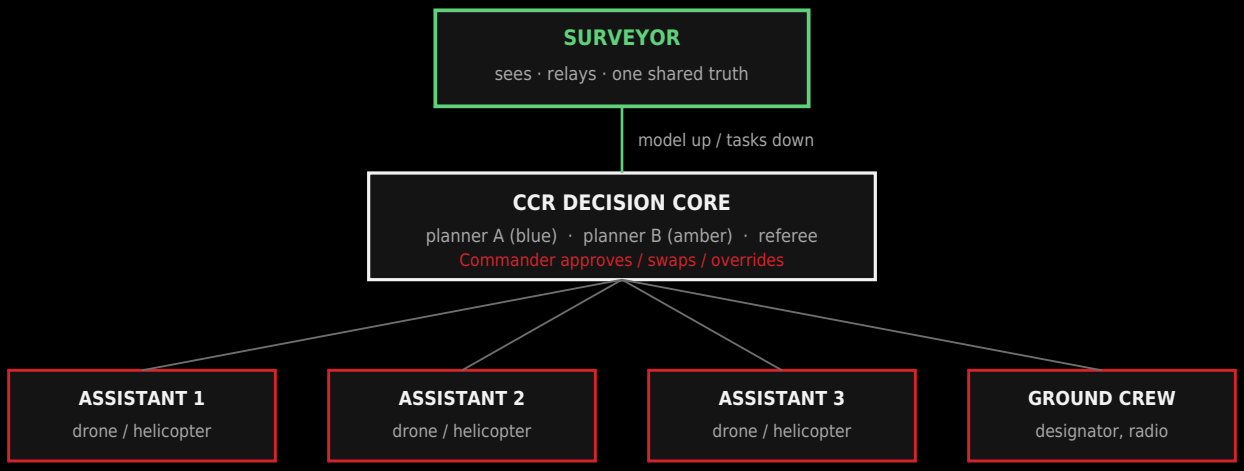


Figure 1 — three layers, three jobs. The surveyor also carries the radio relay that keeps the assistants and the command node in contact over terrain.

02

It is not a new idea: the air attack precedent

U.S. wildland aviation already runs this architecture with people in every box. Under the NWCG Standards for Airspace Coordination, an aerial supervisor — normally the Air Tactical Group Supervisor (ATGS, “air attack”), sometimes a Helicopter Coordinator (HLCO) or a lead-plane pilot — orbits above the fire, assigns every incident aircraft to holding and mission patterns and routes, and directs the tankers and helicopters onto targets. The air attack sees; the Air Operations Branch Director and the incident commander decide at the strategic level; the tankers and helicopters act. Agencies trust this structure because it has worked for decades.

Its known weakness is that it is bound to daylight and visibility: NASA notes that current aerial firefighting is limited to times when a piloted air-attack aircraft can see well enough to direct traffic. NASA's ACERO project exists to lift that limit. Its Portable Airspace Management System, demonstrated in June 2026 with two ground units coordinating drones from an Overwatch aircraft, is described by NASA as providing the air-boss capability for remotely piloted operations, from the ground, in smoke and at night; CAL FIRE's Office of Wildfire Technology is a collaborator. The surveyor-plus-CCR architecture is the same move: keep the air-attack structure the agencies know, and give it eyes that do not need daylight and a coordinator that does not tire.

Role today (NWCG)	Role in the architecture	What changes
ATGS / air attack aircraft	Surveyor (autonomous fixed-wing or multirotor with thermal, EO, LiDAR)	Sees through smoke and darkness; never leaves station for fuel if two rotate
Helicopter Coordinator (HLCO)	CCR tactical planners	Every aircraft gets a drop card each cycle; conflicts resolved by a scorecard
Air Operations Branch Director	The Commander on the CCR tablet	Same authority; sees two options and a margin, approves with one tap
Tankers, helicopters	Assistants: drones first, optionally manned Bell 205s later	Fly the card; terminal guidance closes the last metres
Crews on the line	Ground crew with a coded designator	Can request a drop on a spot without a radio description

03

What each layer contributes that the others cannot

The surveyor

- One shared truth. A single high vantage point produces one georeferenced thermal picture that every other participant works from, instead of each aircraft forming its own partial view. Multi-agent research keeps rediscovering this: a November 2026 framework for post-disaster swarm response puts an integrated sensing-and-communication master high-altitude platform at the top to sense the environment, detect victims and hazards and construct the regions the lower drones are assigned to.
- Persistence. A fixed-wing surveyor loiters for hours at an altitude where it is above the helicopter stack and out of the way; two surveyors rotating give continuous coverage through the night.
- Relay. Line-of-sight radio from a high orbit reaches assistants behind ridges and the command node in the valley; the surveyor is the network as much as the eye.
- Cheap and uncrewed. No payload, no people aboard, so it is the aircraft that can be fully autonomous first and approved first.

The CCR decision core

- Allocation under uncertainty. Which assistant goes to which target, in what order, from which water source, is a scheduling problem with deadlines that move. The research base is explicit that heterogeneous teams handle heterogeneous deadlines better than homogeneous ones, and that this only pays off with a coordinator that allocates well — the CREDS wildfire planner reaches a 100 % success rate at up to four fires per UAV on exactly that basis.
- Conflict made visible. Two planners with different objectives and a deterministic referee turn the speed-versus-safety trade into two lines the Commander can read, rather than one confident answer.
- Human authority, by construction. Recent work on human-centric hierarchical coordination (HECTOR, April 2026) argues that direct control of each robot is impractical and that the operator must interact at several granularities — adding tasks, cancelling, re-prioritising — through a layered scheme. A 2026 wildfire-monitoring architecture goes further and makes mandatory human authorisation a formal state-transition invariant. CCR implements both: tactical options execute inside a pre-approved envelope, global changes stop for the Commander, and every override is logged.
- Reviewability. A logged model snapshot, two option sets and a versioned scorecard are what an after-action review and a certification authority want. A neural swarm cannot give them that.

The assistants

- Mass. The XPRIZE Wildfire finals in September 2026 proved detection and autonomous targeting at small scale and failed to extinguish the test fire for one reason: not enough suppressant. The assistant layer is where payload lives, which is why the operational assistants are optionally manned Bell 205s and not more drones.
- Parallelism. Three assistants cycling on two fronts and a dip site is a throughput the best single aircraft cannot match, and a single loss does not end the mission.
- Precision at the end. The terminal-guidance layer (laser spot, markers, radar altimeter) lives on the assistant, so the surveyor's 1–3 m picture becomes a centimetre drop.
- Verification. In SAR mode the assistants are the second look: the surveyor flags a warm spot, an assistant with zoom and IR confirms a person or dismisses a deer, and the false-positive rate that kills single-sensor searches collapses.

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Evidence that the split works

Three independent lines of evidence point the same way: the military's manned-unmanned teaming programmes, wildland doctrine and NASA's work on it, and the multi-agent research literature of the last two years.

Source	What it shows	Date
USAF Collaborative Combat Aircraft; Marine CCA	Uncrewed aircraft are fielded as teams tasked by a crewed leader, never as independent agents; the leader sees and decides, the CCAs act	Production June 2026; Marine selection Jan 2026
NWCG PMS 520 airspace standards	A single aerial supervisor assigns every aircraft; agencies institutionally require a top-of-stack coordinator	2024 edition
NASA ACERO / PAMS	Air-boss function can move to the ground and run in smoke and at night for remotely piloted aircraft; CAL FIRE participating	Demo June 2026
Mission-capability-aware swarm coordination (Shakeel et al.)	A master high-altitude platform sensing and partitioning the area, with capability-matched drones reallocated between regions, improves mission satisfaction and resource efficiency	Nov 2026
BGC-Nav; CoNav-UAV (cross-altitude SAR navigation)	A high-altitude leader with a global belief plus a low-altitude follower beats single-agent and flat dual-agent baselines on search benchmarks; leader–follower (Stackelberg) training outperforms independent agents by up to 30 points	Oct 2026; Aug 2026
HECTOR (human-centric hierarchical fleet supervision)	Operators cannot control each robot; hierarchical layers with online human interaction cut human effort and computation	Apr 2026
CREDS decentralized wildfire planner	Heterogeneous teams outperform homogeneous ones on mixed deadlines; conflict-aware consensus needed for a global plan	2024
Best-viewpoint coordination for wildfire robots	An observer that keeps an occlusion-free line of sight to the suppressor raises mission effectiveness by 44 %	2024
Governance-constrained wildfire monitoring	Mandatory human authorisation enforced as an invariant reduces false public alerts with limited overhead	Apr 2026
XPRIZE Wildfire finals	Detection in under 10 min and accurate autonomous hits are solved; suppressant mass is the gap	Sep 2026

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The alternatives, and where they fail

Architecture	Strength	Failure mode
One large crewed aircraft doing everything	Simple; agencies know it	Pilot workload is the bottleneck; sees only what the pilot sees; stands down at night; one aircraft, one task at a time
Flat swarm of identical drones with peer-to-peer coordination	Scalable in principle; no single point of failure	No shared truth, so every drone plans on a partial view; no reviewable decision; no payload; agencies cannot supervise it; comms mesh collapses over terrain
Ground-only command with many sensors (towers, satellites)	Cheap, persistent detection	Latency and revisit are too slow for tactics; no relay; no view under the smoke column; XPRIZE showed detection is not the hard part
Autonomous suppressor with its own sensors and no coordinator	Fast local loop (Rain-style aircraft)	Scales to one aircraft; two such aircraft on one fire need exactly the coordinator this architecture adds; no explicit speed/safety trade
Surveyor + CCR + assistants	Shared truth, explicit allocation, human authority, mass where it matters, uncrewed where it is cheap	Dependency on the surveyor and the link — mitigated by rotating two surveyors, a reduced model replica on each assistant, and lost-link behaviours

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How the coordination actually runs

Data flow

- Up: the surveyor streams geo-registered thermal and EO frames and its own pose to the command node (and a reduced feed to each assistant); assistants send telemetry, water/fuel state, drop confirmations and terminal-guidance status; ground crews send designator requests and positions.
- Model: the command node fuses everything into the fire state model (fires, hot spots, assets at risk, aircraft, water sources, obstacles, weather) with timestamps and confidences.
- Down: CCR issues global plans on material change and a tactical drop card to every tasked assistant each cycle; the Commander's approvals and overrides ride the same channel.

Timing

Loop	Period	Who closes it
Thermal mosaic update	2–5 s	Surveyor + processing tier
Tactical drop card per assistant	5–15 s	CCR planners + referee; Commander only if disagreement or envelope exit
Global re-plan	On trigger (new fire, wind shift, aircraft state) or every few minutes	CCR + Commander approval
Terminal guidance	10–50 Hz	The assistant itself, on its own sensors
Surveyor rotation	Every 2–6 h	Second surveyor overlaps before the first leaves station

Degraded modes

- Surveyor link lost: assistants continue the current card to completion on their own sensors, then hold at a pre-briefed point; the second surveyor is called forward; the Commander is told in one line.
- Command node lost: the surveyor's reduced model replica issues hold-and-return instructions; no new drops without a decision core.
- Assistant lost: the model marks it, both planners re-plan, the referee presents the consensus or the conflict.
- Planners disagree beyond threshold repeatedly: the referee reports the pattern and the Commander sets a standing override, which is logged and fed back.

Communication topology

Star through the surveyor for reach, with a direct ground link from the command node to any assistant in line of sight, and an assistant-to-assistant short-range mesh for separation only. The surveyor carries the long-range radio because it is the one node that can see everyone; the architecture degrades gracefully because the terminal loop never depends on any link at all.

07

The same architecture, two missions

Wildfire

The surveyor builds the thermal mosaic and the fire behaviour projection; CCR allocates assistants to fronts, spot fires and dip sites with the speed-versus-safety trade explicit; assistants drop on laser-designated or thermally tracked spots and dip on marker-guided hovers; ground crews request drops with a designator. The structure is the ATGS/HLCO structure the agency already uses, with the night and smoke limits removed. The March 2027 demonstration shows all of it at candle scale with one surveyor drone and two or three X650-class assistants.

Search and rescue

The surveyor (mothership) flies high with the best thermal camera, builds a 3D mesh of the search area and flags warm spots; CCR ranks the spots by probability (terrain, last known position, time, temperature signature) and dispatches assistants with zoom and IR to verify each one, with one planner optimising coverage speed and the other optimising certainty and crew safety; confirmed detections go to the SAR chief with a one-tap approval for the next action. Cross-altitude leader–follower navigation is precisely the configuration the 2026 research shows outperforming single aircraft on search benchmarks, and the verification step is what removes the false positives that exhaust a single-sensor search. The same four aircraft that fight the fire in summer search the San Juans in winter.

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Why the combination delivers the best possible solution

1. It assigns each job to the layer that is best at it — seeing to a persistent uncrewed observer, deciding to a reviewable dual-planner core under a human, acting to aircraft with payload and precision — instead of asking one aircraft or one swarm to do all three badly.
2. It is the structure agencies already trust, the ATGS/HLCO stack, with its two known limits (daylight, human bandwidth) removed rather than its authority removed.
3. It matches where the technology is in 2026: uncrewed is easy where there is no payload and hard where there is; the architecture puts the uncrewed aircraft on top and the optionally manned ones below.
4. It is the architecture the research keeps converging on — a high observer with a global belief, capability-matched lower agents, hierarchical human supervision and explicit conflict resolution — and the one the military has turned into production programmes.
5. It fails gracefully. Every layer has a degraded mode, the terminal loop needs no link, and the decision core's disagreement is information rather than a crash.

Sources: NWCG Standards for Airspace Coordination PMS 520 (2024); NASA Ames, “NASA Demonstrates New Wildland Fire Airspace Management System” (June 2026); Air Force / Air & Space Forces Magazine on CCA Increment 1; Breaking Defense on the Marine CCA; arXiv 2611.03728 (Shakeel et al., mission-capability-aware swarm coordination, Nov 2026); arXiv 2610.14702 (BGC-Nav); arXiv 2608.01802 (CoNav-UAV); arXiv 2604.10892 (HECTOR); arXiv 2407.19163 (CREDS); arXiv 2410.08602 (best-viewpoint wildfire coordination); arXiv 2604.04265 (governance-constrained wildfire monitoring); Ars Technica on XPRIZE Wildfire (Sep 2026). CCR — Conflicting Computer Resolver — © Helen-B Advanced Engineering.