

Risk-Aware Tanker Basing and Scheduling for Contested Air Refueling Operations

Know the threats early: wipe out ground risk. Learn them late: still cut 9.3%. Use either layer — or both.

Nathan Yoon · Evan Hoch Faculty advisor William McEntee Host organization MIT Lincoln Laboratory, Group 42



THE HEADLINE RESULT

If threat zones are known and tankers can be assigned before the scenario starts, pre-scheduling can cut ground-interval risk by **100%**. If zones are only known after scheduling, post-scheduling still cuts risk by **9.3%**. Use either layer alone, or both together.

−100% PRE-SCHED GROUND RISK total ground-interval risk after laydown optimization	−9.3% POST-SCHED GROUND RISK after one-move repositioning mitigation	−0.06% TOTAL FUEL BURNED post-sched: slight reduction, not a penalty	100% REFUELINGS COMPLETE post-sched preserves every aerial refueling request
---	--	--	--

THE PROBLEM

01 Tanker aircraft vulnerability

Tankers enable long-range operations, but are vulnerable to missile threats.



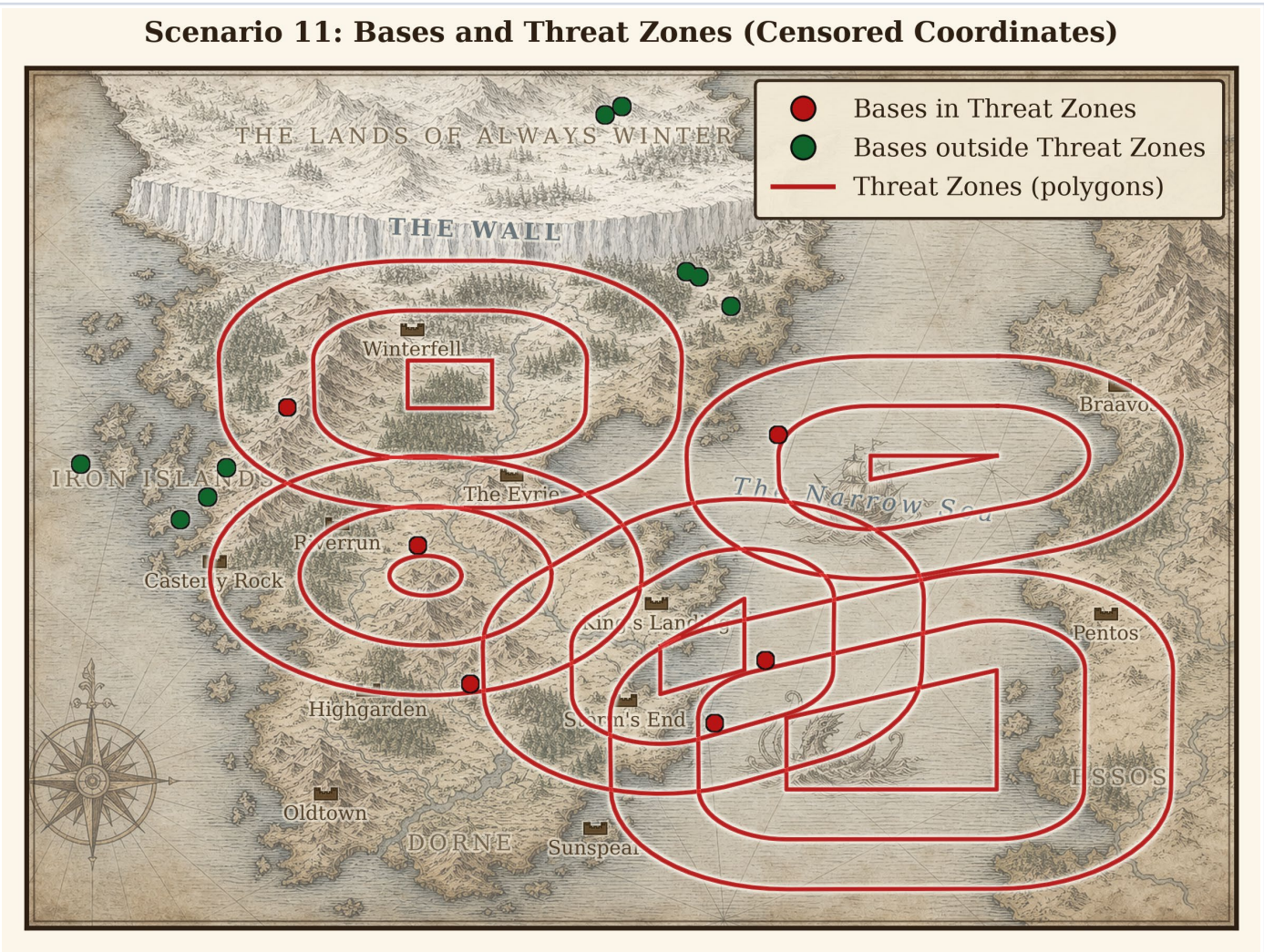
A KC-135 Stratotanker refueling an F-15



A surface-to-air missile mid-launch

Tankers are most vulnerable when parked on the ground. Loss has devastating effects: personnel, follow-on mission failure risk, and significant taxpayer cost.

02 Where the ground risk lives



Benchmark scenario · 6 of 15 bases sit inside layered threat zones (geography censored).

5,000 MISSIONS	375 TANKERS	6 of 15 BASES EXPOSED	5 THREAT ZONES
----------------	-------------	-----------------------	----------------

Exposed bases are not busier than safer ones nearby — they simply sit in the wrong place. That means the danger can often be redesigned or relocated, not only accepted.

03 How we score parked risk

chance of loss = $1 - e^{-\Lambda \times \text{parked hours}}$

Λ = airfield hazard rate from Lincoln Lab threat maps

Longer parking under threat raises the odds of being hit. Rates come from Lincoln Lab threat data — we do not invent them.

WHAT IT IS WORTH

≈ 22 tankers	above 0.9 ground-risk cut (68 → 46)
≈ \$4.4B	airframe value preserved (~\$200M FY'27)
≈ \$0	net cost — fuel falls, offload preserved

Order-of-magnitude only, one benchmark — model expectations, not a validated cost analysis.

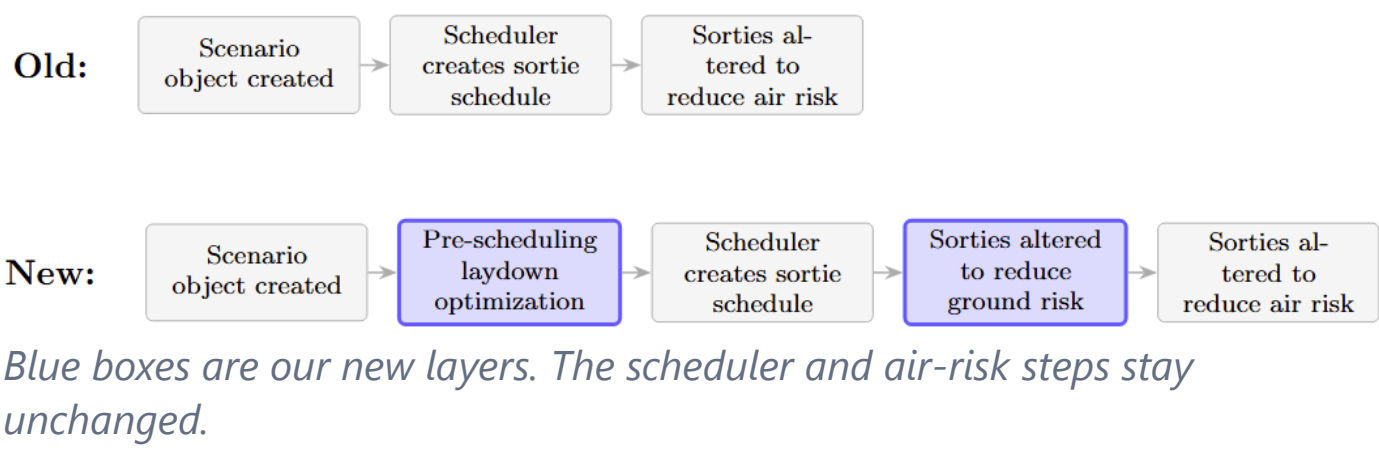
HOW WE TACKLED IT

04 The Lincoln Lab scheduler

Group 42's production tool builds the flight plan we wrap around — we do not rewrite it.

WHAT THE SCHEDULER DOES

Inputs: tanker-to-base assignments and aerial refueling (AR) requests. Output: a sortie schedule for each tanker — which tanker meets which fighter, when, and from which base.



We add two optional layers around that scheduler: pre-scheduling before it runs, and post-scheduling after it finishes. Either can be used alone, or both together.

05 Pre-scheduling methodology

Before the scheduler runs, choose a starting base for each tanker so demand stays supportable and less exposed.

STAGE 1 · INITIAL LAYDOWN

- Decision: assign every tanker to exactly one base
- Objective: minimize average risk to air-refueling locations for each tanker-base pair
- Status: solves quickly at full scale

STAGE 2 · SUPPORTABILITY

- Decision: assign requests to tankers under the Stage 1 laydown
- Objective: maximize requests with at least one supporting tanker
- Constraints: coverage, reachability, temporal deconfliction
- Status: still computationally expensive at full scale

06 Post-scheduling methodology

After the scheduler finishes, ask for each tanker: would parking somewhere safer between missions cut its risk?

OBJECTIVE · AT MOST ONE REBASE

- Minimize expected tankers lost on the ground
- Accept a move only if that tanker is strictly safer

DECISION & CONSTRAINTS

- Stay put, or move once to a safer base between missions
- Aerial refueling tanker pairs stay fixed
- Every aerial refueling requirement still completes

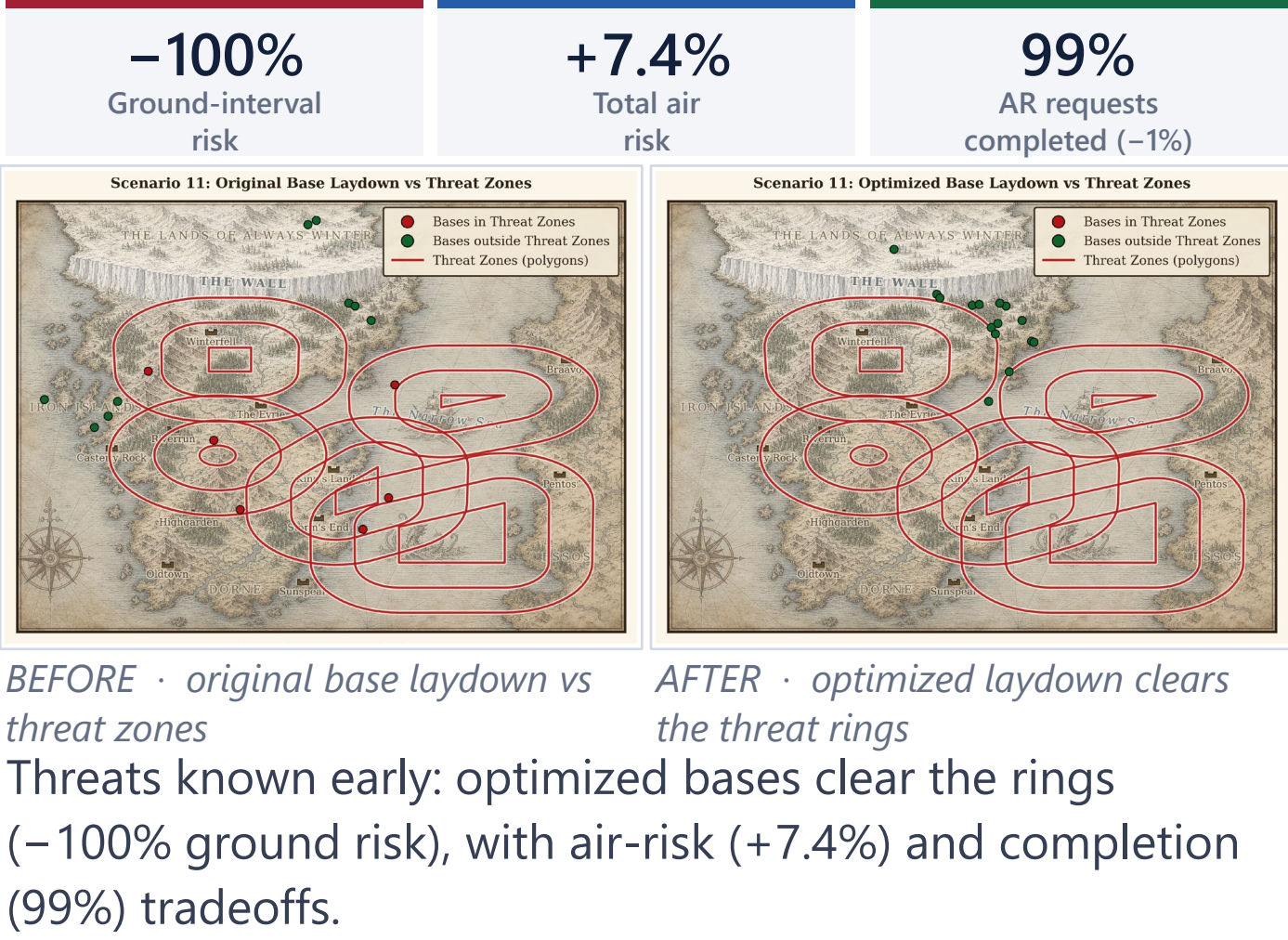
Every accepted change is one visible repositioning flight a planner can accept or reject — not a black-box rewrite of the schedule.

FINDINGS

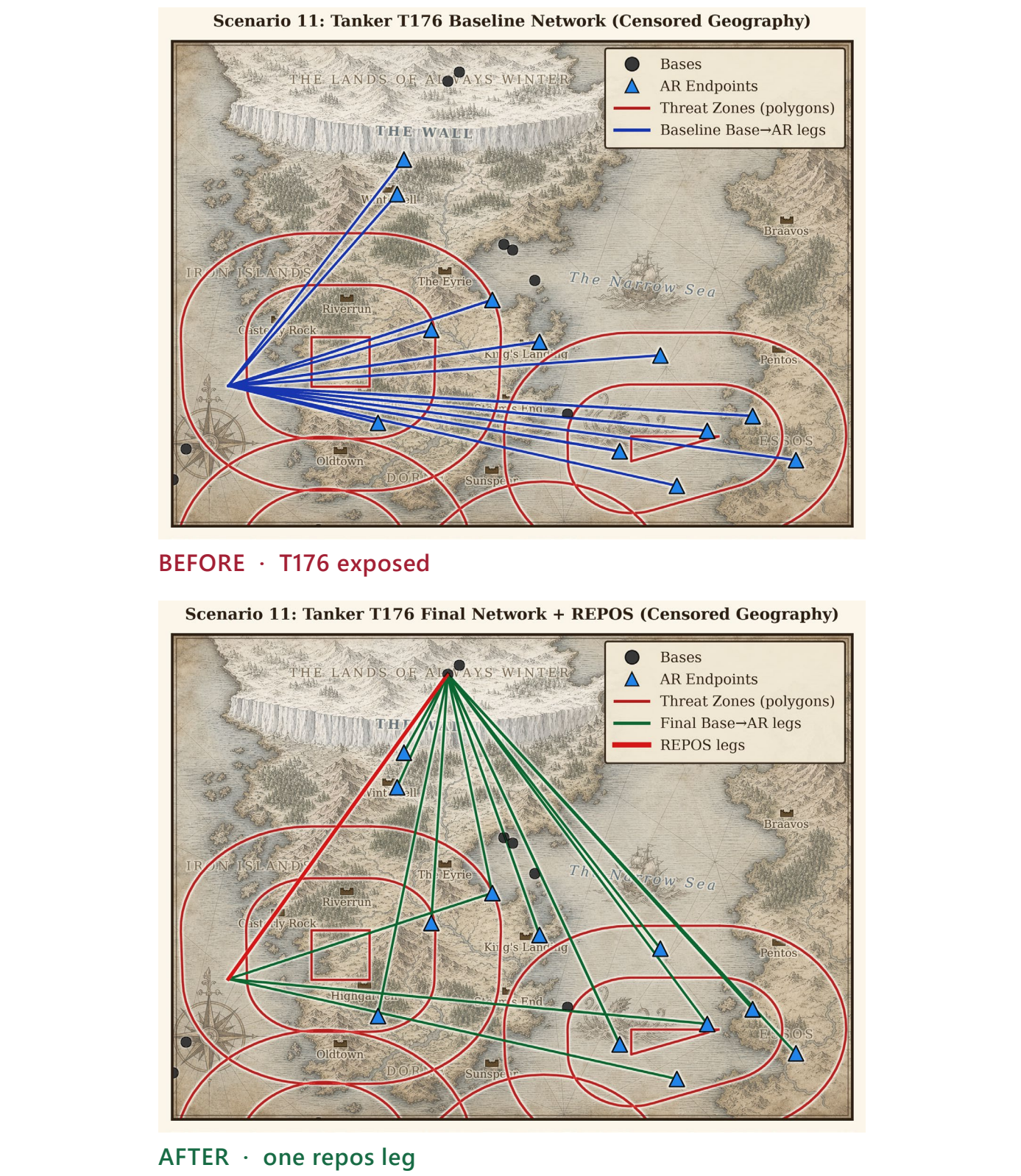
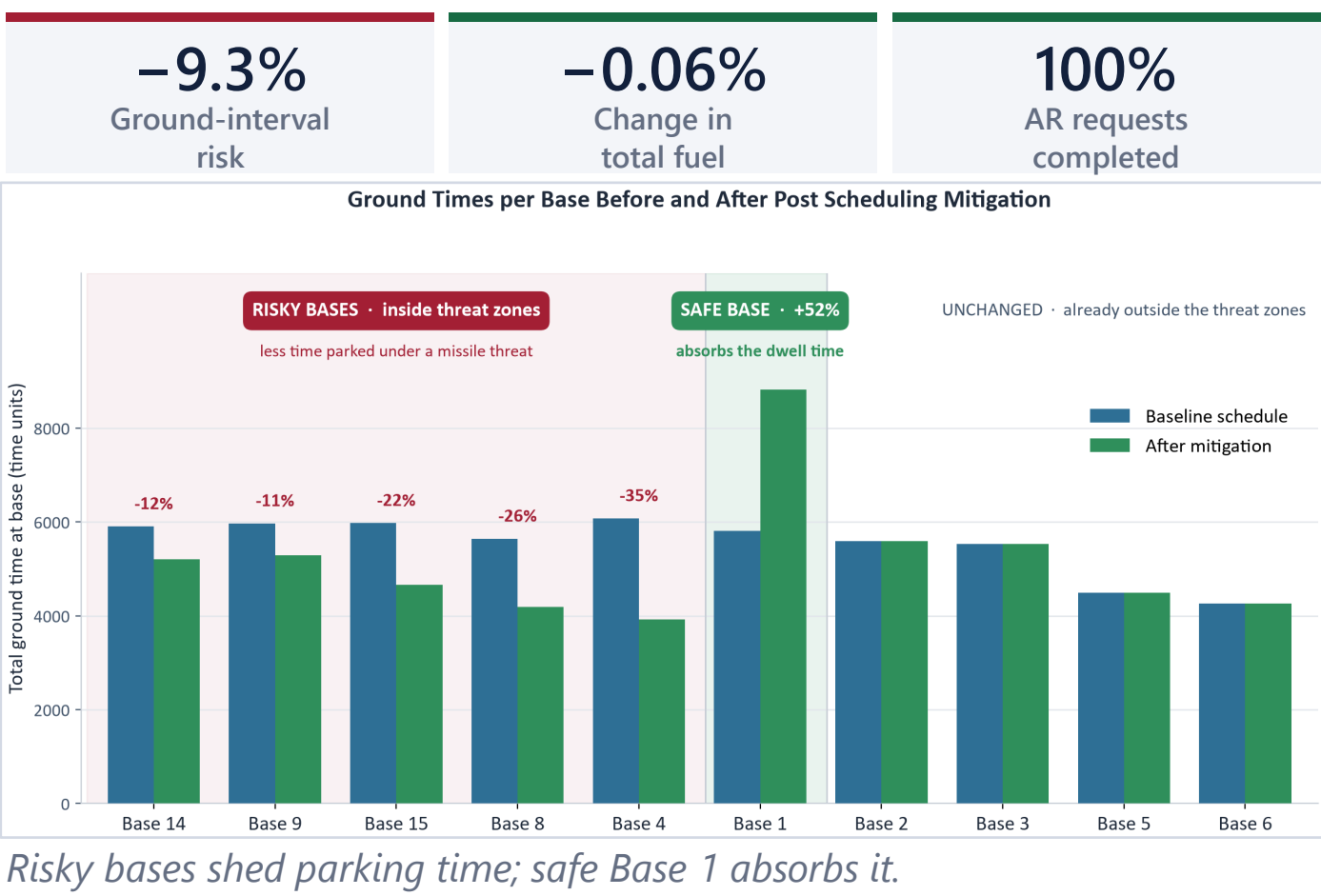
- Pre-scheduling can cut ground risk dramatically — with air-risk and completion tradeoffs.
- Post-scheduling achieves more modest gains without compromise.
- The two methods are modular and can run separately or in tandem.

WHAT WE FOUND

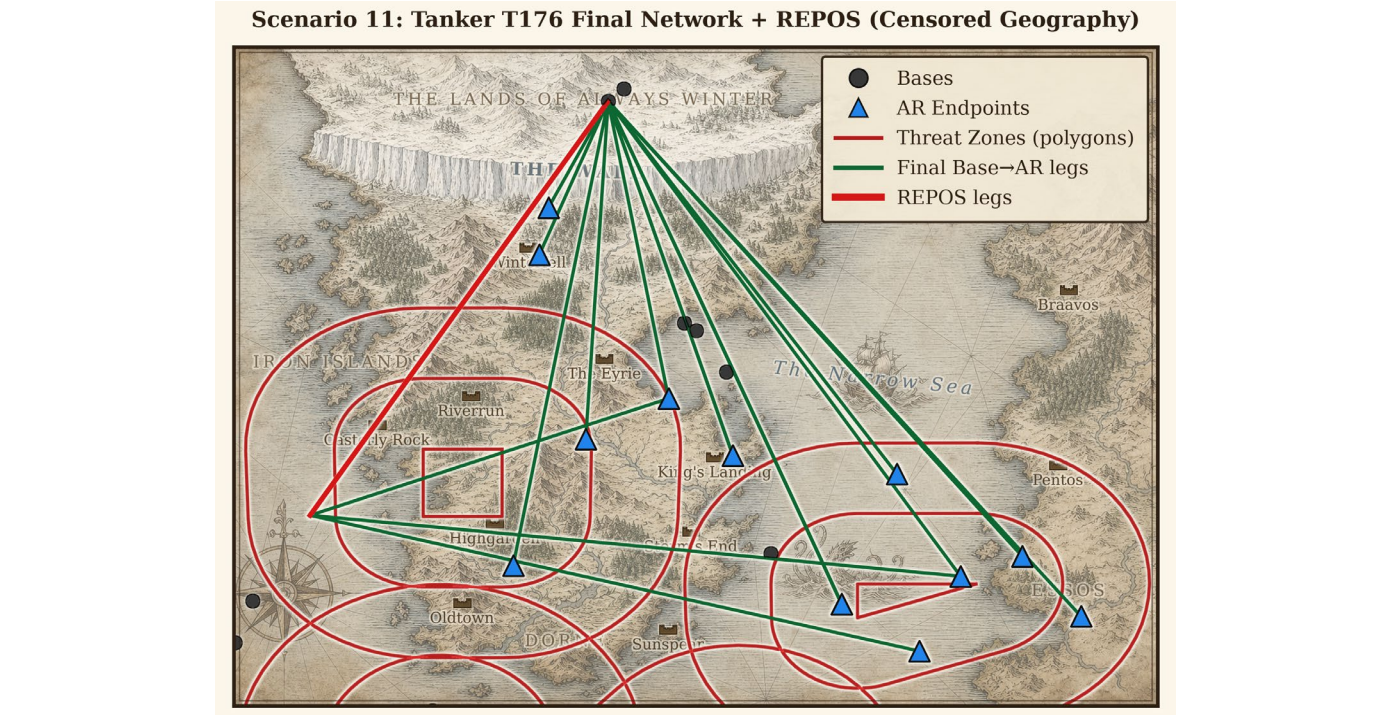
07 Pre-scheduling results



08 Post-scheduling results



BEFORE · T176 exposed



AFTER · one repos leg

Threats known only after scheduling: −9.3% ground risk, no fuel penalty, 100% AR complete. ~22 fewer tankers above 0.9 risk (68 → 46).

TAKEAWAY

Know threats early and assign bases first: ground risk can fall 100%. Learn them only after scheduling: still cut 9.3%. Either layer works alone; both can run together.

OPEN QUESTIONS & NEXT

- Tractability — request-level Stage 2 without extreme cost
- Richer moves — highest-risk tankers may need more than one rebase
- Join the layers — optimized laydown → scheduler → post-sched
- Integration — Group 42 codebase and USTRANSCOM workflows

The views expressed in this document are those of the author and do not reflect the official policy or position of the United States Air Force, the Department of War, or the United States Government.