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جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

AI-Enabled Multi-Layer NTN for Rapid Target Acquisition in Desert Search and Rescue

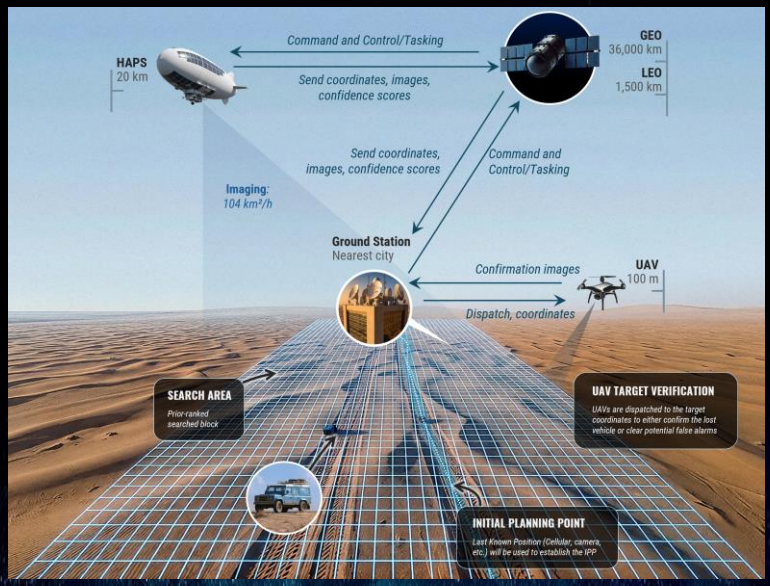
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Introduction

In one year, Saudi rescue teams recorded more than 13,000 stranded vehicles in the Kingdom's deserts. 28 people died of exposure, and 14 were never found. They had no connection and no beacon, so they could not call for help.

You cannot find a silent car by listening. You have to see it.

We propose a multi-layer NTN for search and rescue: HAPS image the desert from 20 km, a satellite link carries the results to a ground station, and UAVs confirm the detections. We show that the **satellite link,** limits the search, and that running the AI on the HAPS removes this limit.



Ground-Based

Fully sent to the ground

17.3 Mbps

HAPS-Based

Onboard inference: only detections sent down to the ground

0 Mbps *a few bytes*

Hybrid

send around 2.5% (compressed)

0.43 Mbps

TABLE II · OPERATING-POINT SELECTION AT 18 cm

conf	P_D	FA / km²	FA per 20,000 km²
0.20	0.901	0.0393	785
0.30	0.870	0.0208	416
0.35	0.854	0.0139	277
0.40	**0.845**	**0.0116**	**231**
0.45	0.822	0.0023	46

CHOSEN PARAMETERS

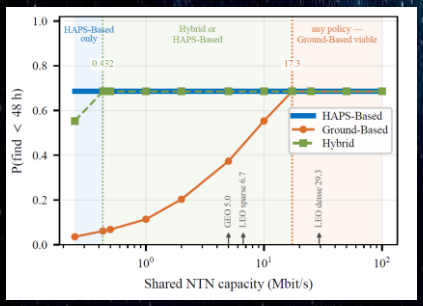
0.845 probability of detection

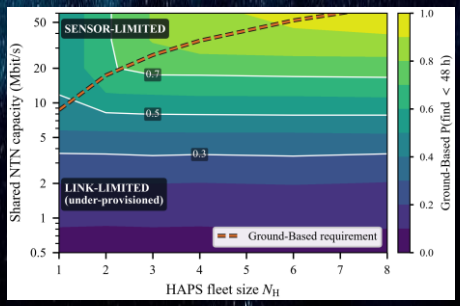
231 false alarms / 20,000 km²

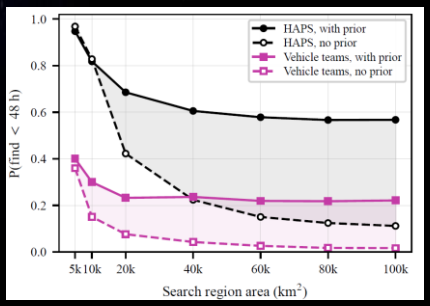
How many false alarms can the UAVs clear?

Two UAVs flying at 90 km/h can clear **240 candidates** in a 20,000 km² area









What is innovative?

The search rate of a HAPS is the minimum of what its camera can image and what the satellite link can carry. In practice, the link is the bottleneck: at 104 km²/h each HAPS needs **8.65 Mbit/s** if every image is sent down.

Our innovation: we treat **where the AI runs** as a network design choice, and derive in closed form the capacity the link needs. For two HAPS, filtering on board cuts it from **17.3 to 0.43 Mbit/s, forty times less**. Below 1 Mbit/s, sending every image finds fewer than 10% of vehicles within 48 hours, however good the detector is.

How does it relate to sustainability?

- **Saving lives:** about 3× higher chance of finding a lost vehicle within the 48-hour survival window than vehicle search teams (69% vs 24%).
- **No fuel:** the HAPS is solar-electric. Responders drove 1.7 million km in a single year in fuel-powered vehicles.
- **Less flying, low power:** UAVs fly only to detected candidates; the on-board AI runs on a Jetson-class computer at tens of watts.

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