ASPS: Dynamic Localized Positioning System

Mid-Term Progress Report

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Presentation Overview

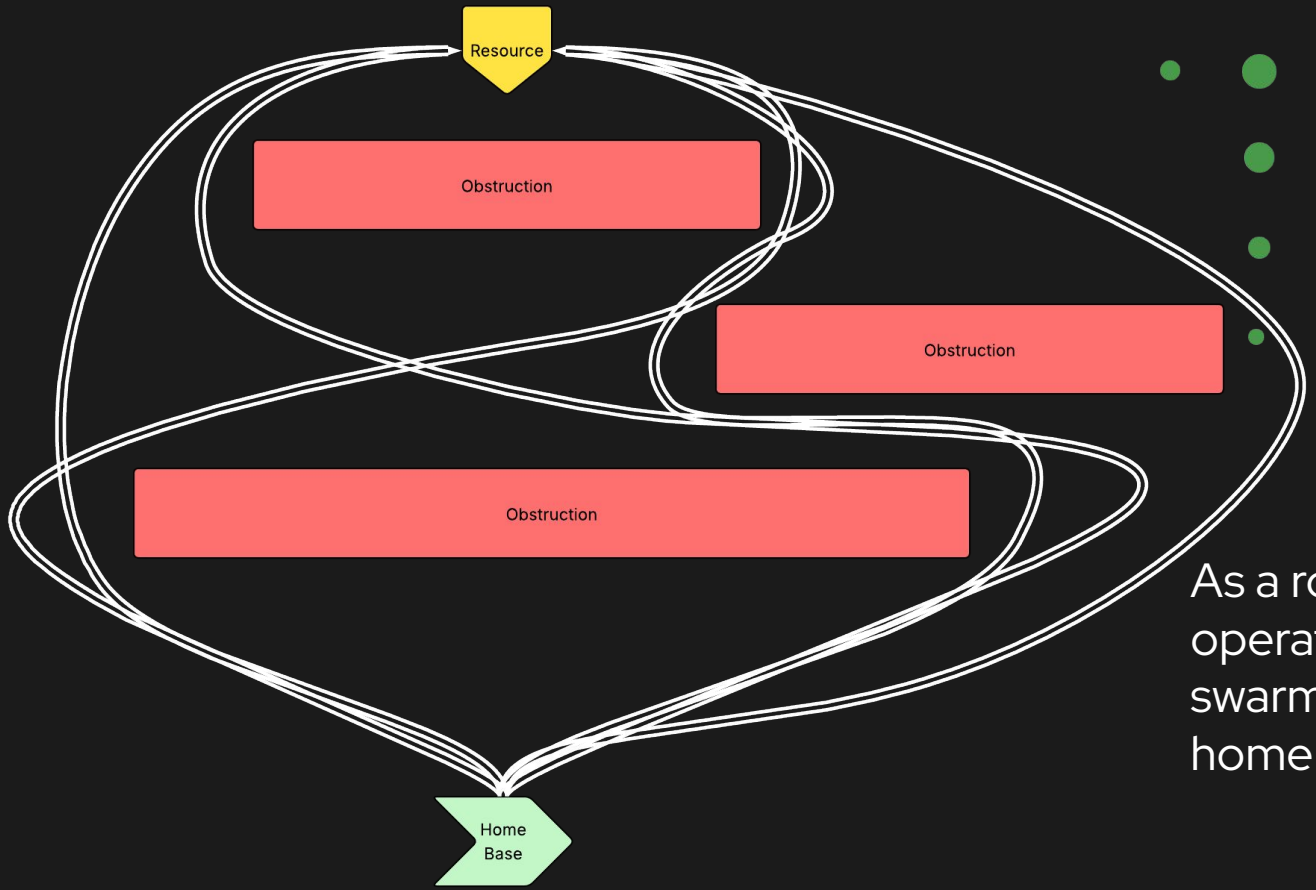
- My journey until now
- Path Finding and Persistence
- Problem Statement and Proposed Solution
- The ASPS Network
- Comparing MEO and ASPS
- Milestones toward a PoC

From Decision-Making to Localized Positioning Systems

- Started with Quorum-Based Decision Making among robots in a swarm. Proved to be too broad of a subject
- Realized that the scope must be narrowed to solve any real-world problems
- Discovered that operating in GNSS-constrained environments is a challenging and active area of research and innovation
- Determined that there is little research into deploying localized positioning systems into active SAR environments
- Selected this as my focus area and created the concept of the ASPS (more on this later)

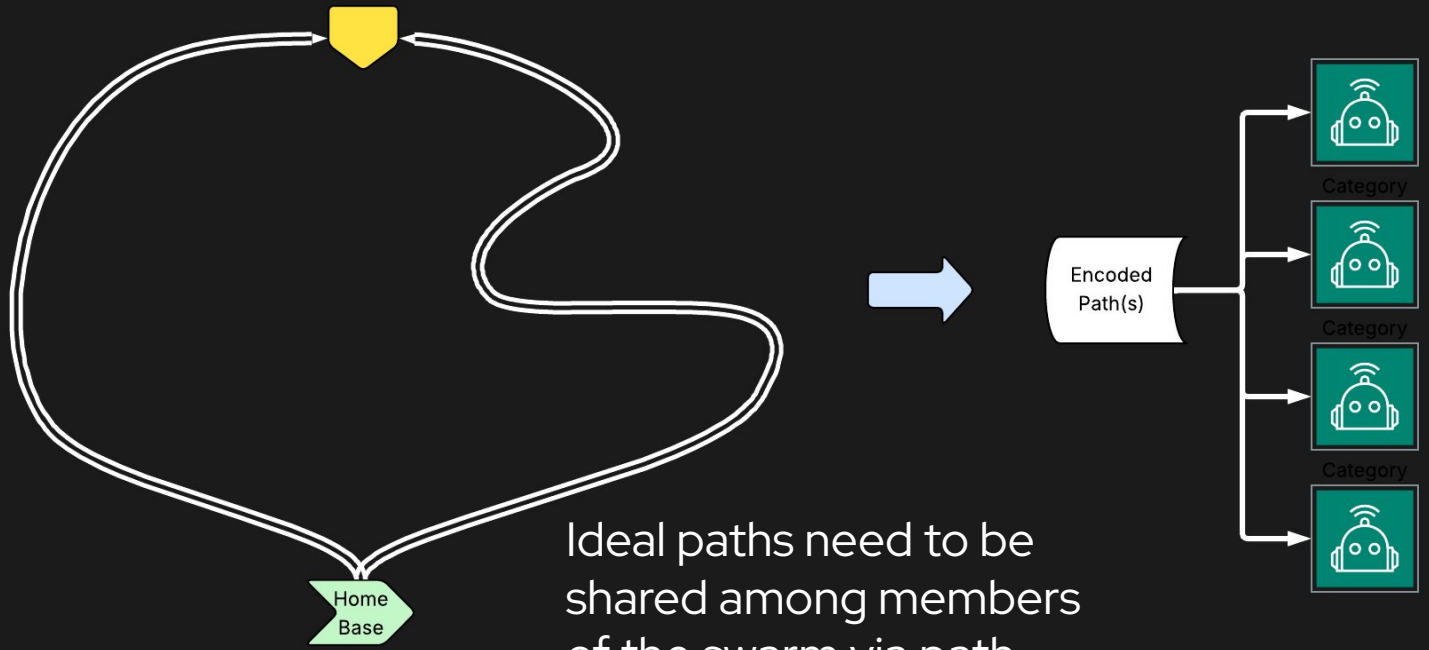
Overview of Pathfinding and Path Persistence

Pathfinding



As a robot swarm operator, how does the swarm find a path from home base to the target?

What is Path Persistence?



Ideal paths need to be shared among members of the swarm via path encoding and transmission

“Being the Path” vs. “Deploying the Path”

- “Being the Path” means that the swarm, or a subset of, forms a physical chain representing the path
- “Deploying the Path” means that a path is laid out by the swarm as it is discovered
- The physical chain of swarm agents is expensive to maintain
- Deployed paths are static and difficult (or impossible) to change once they are deployed
- Both methods are single point of failure (SPOF)

Challenges with Path Persistence

- The False Map problem, i.e. Dynamically changing terrain
- Persisted paths must be constantly updated as the environment changes
- Dead Reckoning, i.e. Death by accumulated error from inertial navigation systems (INSs)
- Physically and/or computationally expensive without GNSS/GPS
- GNSS/GPS denied environments make pathfinding and path repair difficult or impossible

The problem

The unpredictability and volatility of the environments in which SAR swarm agents typically operate in results in a complex matrix of tradeoffs between the various path generation and persistence options.

GNSS/GPS is an ideal system due to its highly precise positioning and low cost, but SAR environments commonly have unreliable (or zero) access to it.

Proposed solution

Create a localized positioning system (LPS) utilizing a small cluster of aerial swarm agents. This capability is known as the **Area Swarm Positioning System** (ASPS).

While the robots comprising the ASPS network are higher cost, the path discovery and recovery robots can be made far cheaper and deployed in a swarm for resilience, failure recovery, and path verification as they now all have access to the high-precision, localized positioning network.

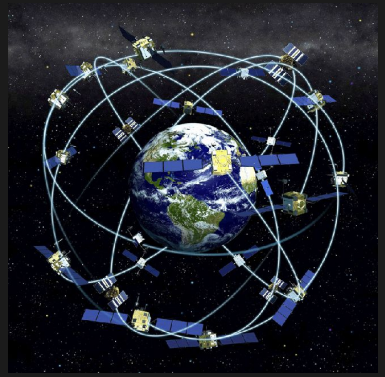
The ASPS Network

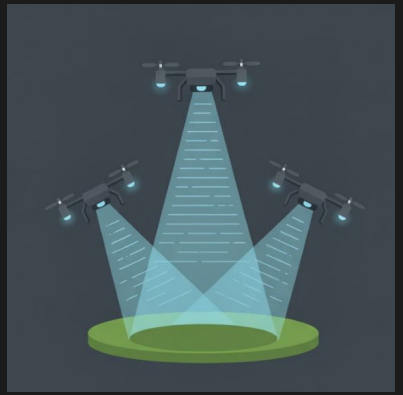
- Aerial drones carry specialized hardware for emitting position signals
- The drones are positioned by human operators and remain relatively static
- The ASPS network is initialized over a wide, local area
- A swarm of robots is deployed utilizing the ASPS as their positioning system
- Dynamic replacement of ASPS member drones allows for very long mission times without ASPS network downtime

But... GPS is complicated!

Yes it is, however much of that complexity is related to the fact that GPS/GNSS is deployed in medium earth orbit (MEO) and must remain functional at all times.

The ASPS does not have to be active 24/7, it is deployed close to the earth's surface, and it is not in orbit. The positioning system itself can also be precisely re-positioned on-demand to best fit the operational environment.





GPS is complicated... contd.

Medium Earth Orbit

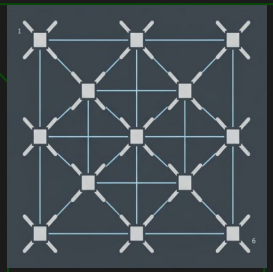
- → Weak Signal Strength
- → Weak Signal Penetration
- → Line-of-sight issues
- → Weaker signal results in higher chance of multipath errors
- → Zero deployment control; we are passive users of GNSS
- → Long Time to First Fix (TTFF)
- → Uni-directional comms; GNSS is "transmit only"

VS

ASPS (Near Earth)

- → Very strong signal strength
- → Strong signal penetration
- → Flexible deployments can improve LoS issues
- → Strong signal massively reduces signal2noise ratio and multipath errors
- → Total deployment control
- → Much lower TTFF since we have total control over the "almanac", i.e. deployment locations
- → Bi-directional comms

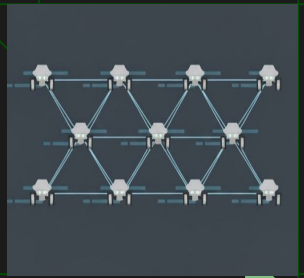
How it could work



1

ASPS Agents Are Deployed

An ASPS network is formed using a small cluster of aerial agents



2

Recovery Agents are Deployed

Cheap, simple, GPS-dependent robots are deployed as a swarm for pathfinding and target acquisition and recovery

3

ASPS Network Utilized for Target Recovery

ASPS replaces GPS for precise positioning enabling faster, more reliable target acquisition and recovery in highly dynamic and volatile environments.

What's Next?

The Road to a Proof of Concept

Milestone 1 ✓

Define the problem statement, the capabilities of ASPS, and formulate a reasonable PoC goal

Milestone 2

Research the GNSS/GPS protocol and attempt to replicate a very basic version using LoRa or comparable medium-long range RF signals from 3-4 static ASPS network devices

Milestone 3 --

Implement a receiver for the basic ASPS network and use it to position a very simple singular robot. The positioning is expected to be very imprecise at this milestone.

Final PoC --

Using two modes of operation: Path-Gen and Path-Follow, see if the robot can operate in these two modes utilizing only the ASPS for localized positioning

Stretch Goal --

Utilize multiple robots. One robot operates in Path-Gen while the others operate in Path-Follow using the persisted path and positioning data from the ASPS

Thank you!

Questions?