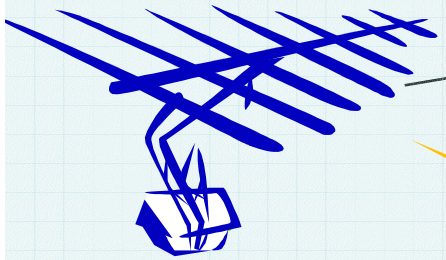
Cooperative teams of Unmanned Aerial Vehicles

CompSci Graduate Co-Op

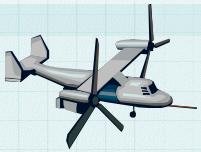
ThanhVu H. Nguyen

Supervisor: ***Dr. James F. Smith, III***

Naval Research Laboratory,
Washington, DC



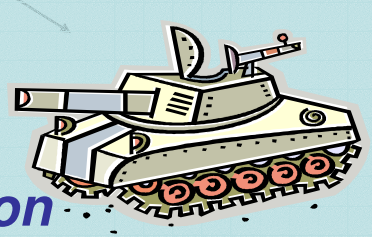
Interferometer



measures
index of refraction

Atmosphere
layer

Electromagnetic
wave emission
from



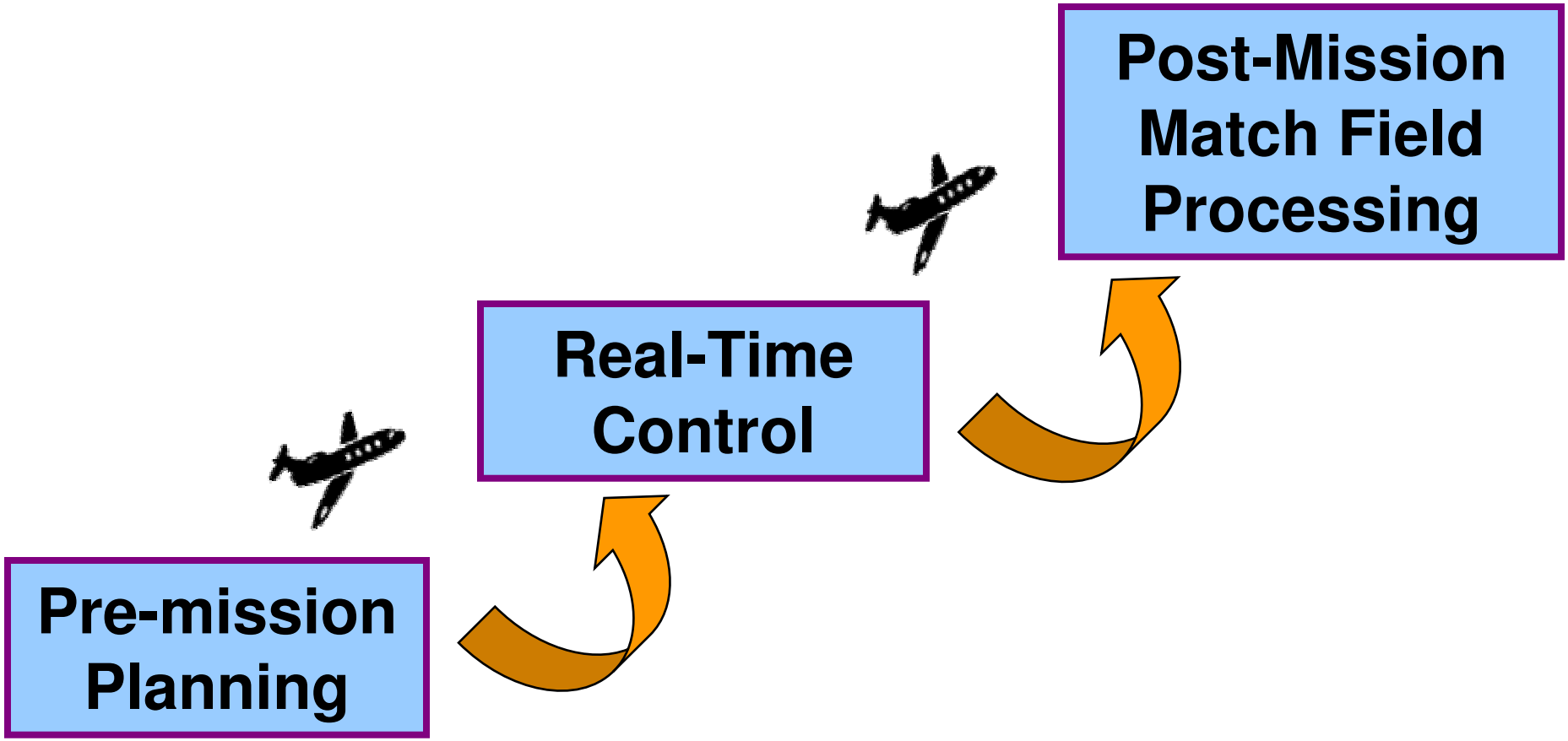
Unknown Enemy location

PROBLEM DESCRIPTION:

Determining the location of an electromagnetic source (EMS), generally a radar

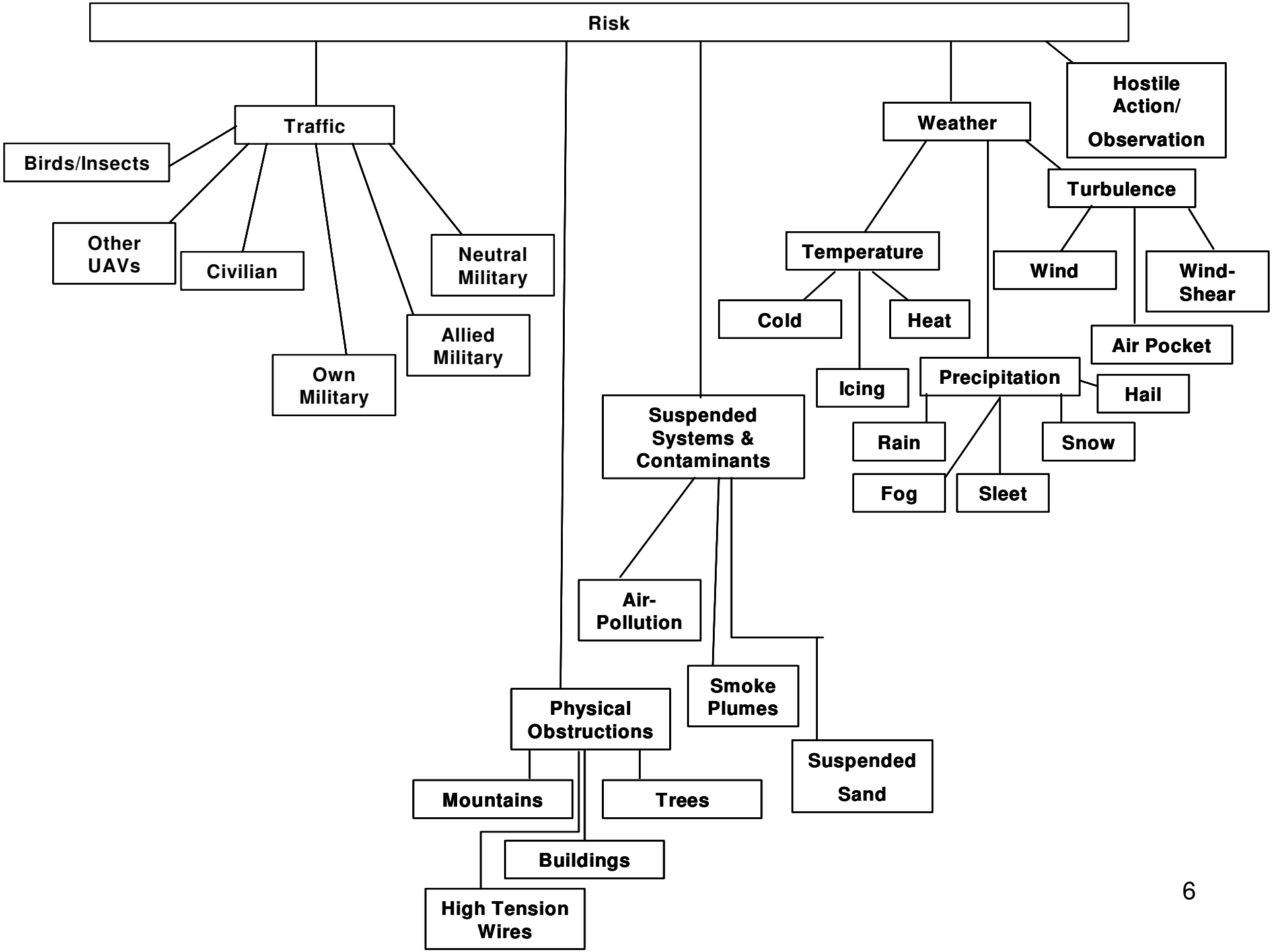
APPROACH: Send UAVs to measure index of refraction in the atmosphere. Use Match Field Processing (MFP) method on those values to estimate the position of the EMS

Overview of UAV Planning, Control and Post-Mission

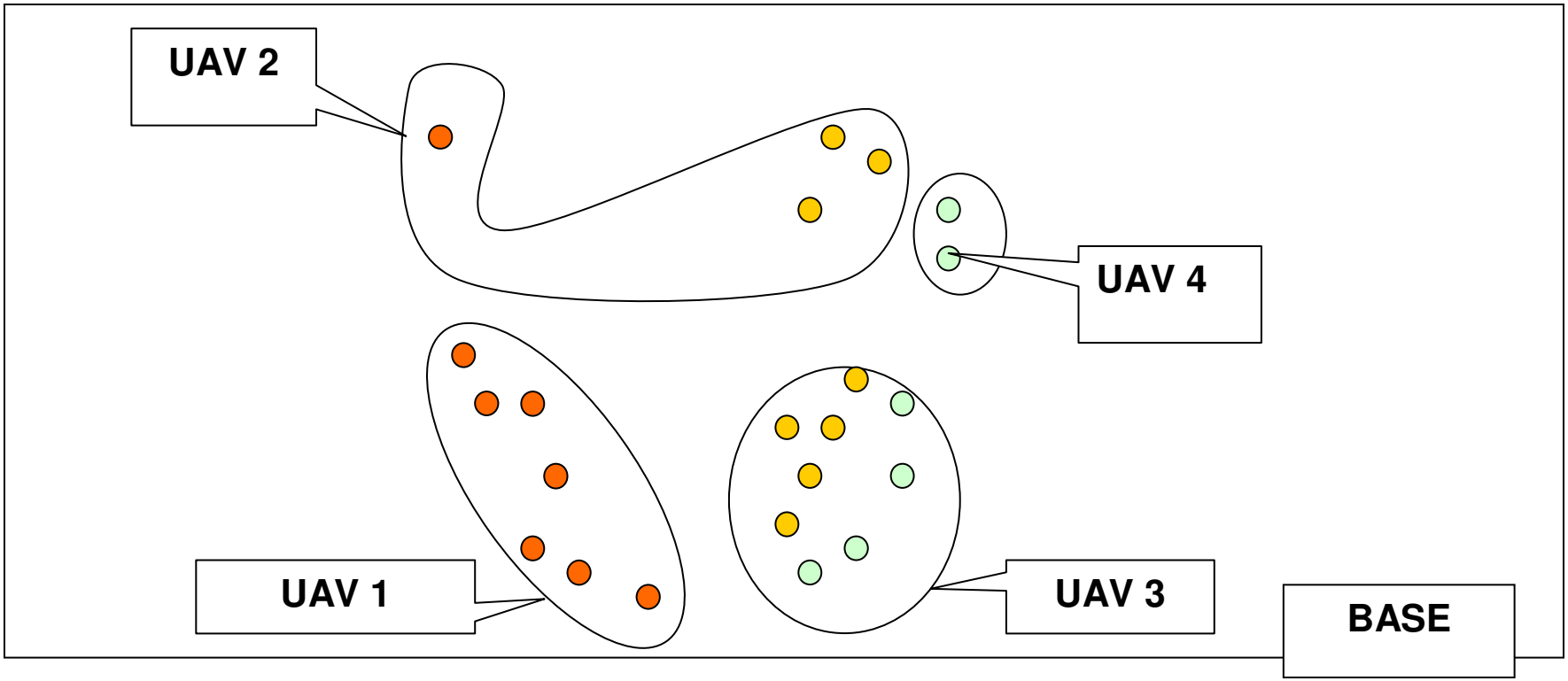


Planning Phase

- **Planning Algorithm**
  - Determines optimal number of **UAVs**, optimal trajectories, **UAV** sampling patterns, and resource allocation prior to mission.
  - Determines optimal path of each **UAV**, while routing UAVs around turbulence and other threats
  - Takes into consideration the following constraints: fuel, battery life, risk, **UAV** cost, and importance of various points for sampling.


Risk
Traffic
Birds/Insects
Other UAVs
Civilian
Own Military
Allied Military
Neutral Military
Weather
Temperature
Cold
Heat
Icing
Wind
Turbulence
Wind-Shear
Air Pocket
Precipitation
Rain
Fog
Sleet
Snow
Hail
Hostile Action/ Observation
Suspended Systems & Contaminants
Air-Pollution
Smoke Plumes
Suspended Sand
Physical Obstructions
Mountains
Trees
Buildings
High Tension Wires

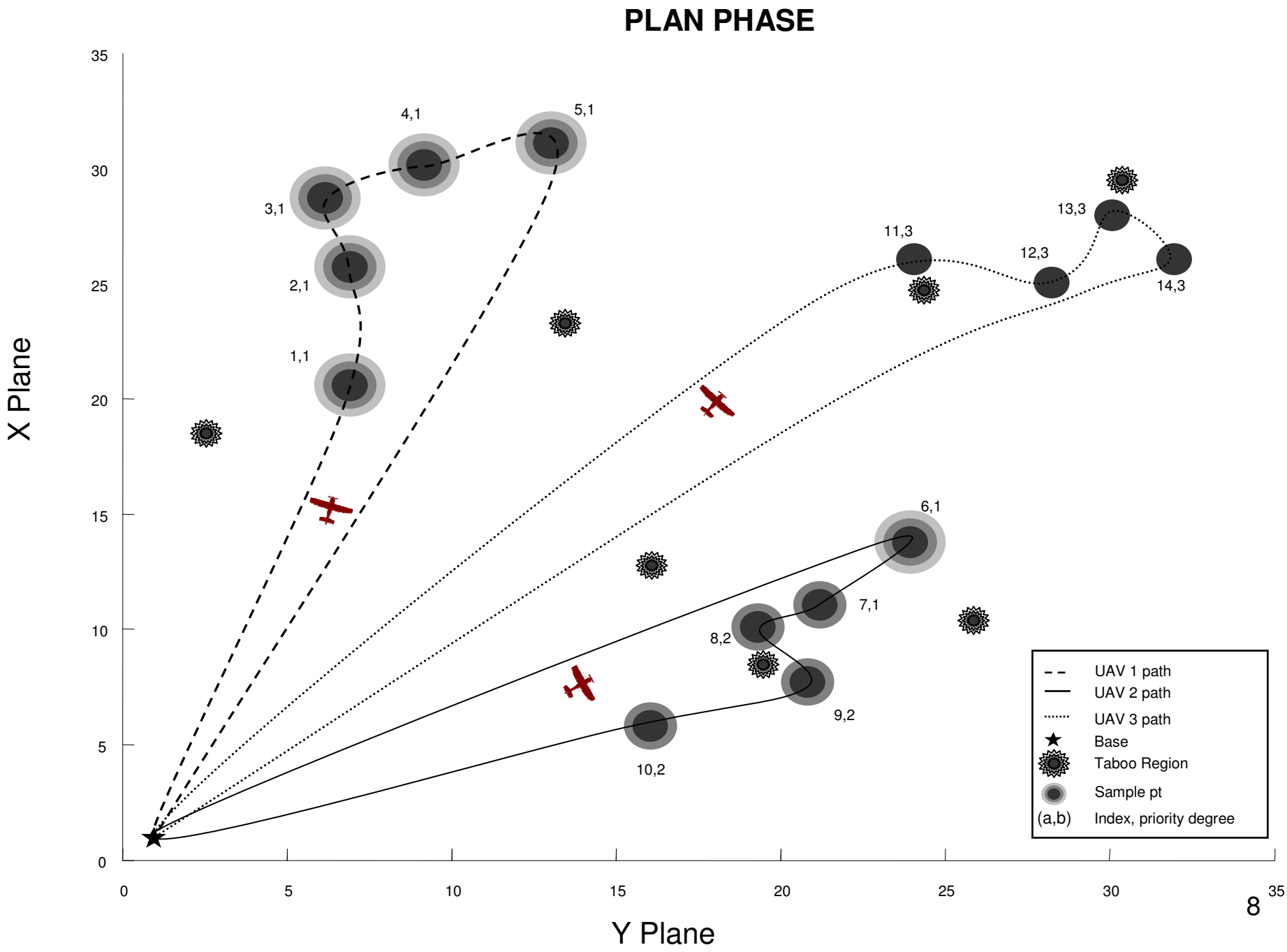
Assigning UAVs to Sample Locations of Varying Priorities



Red dot = highest priority,

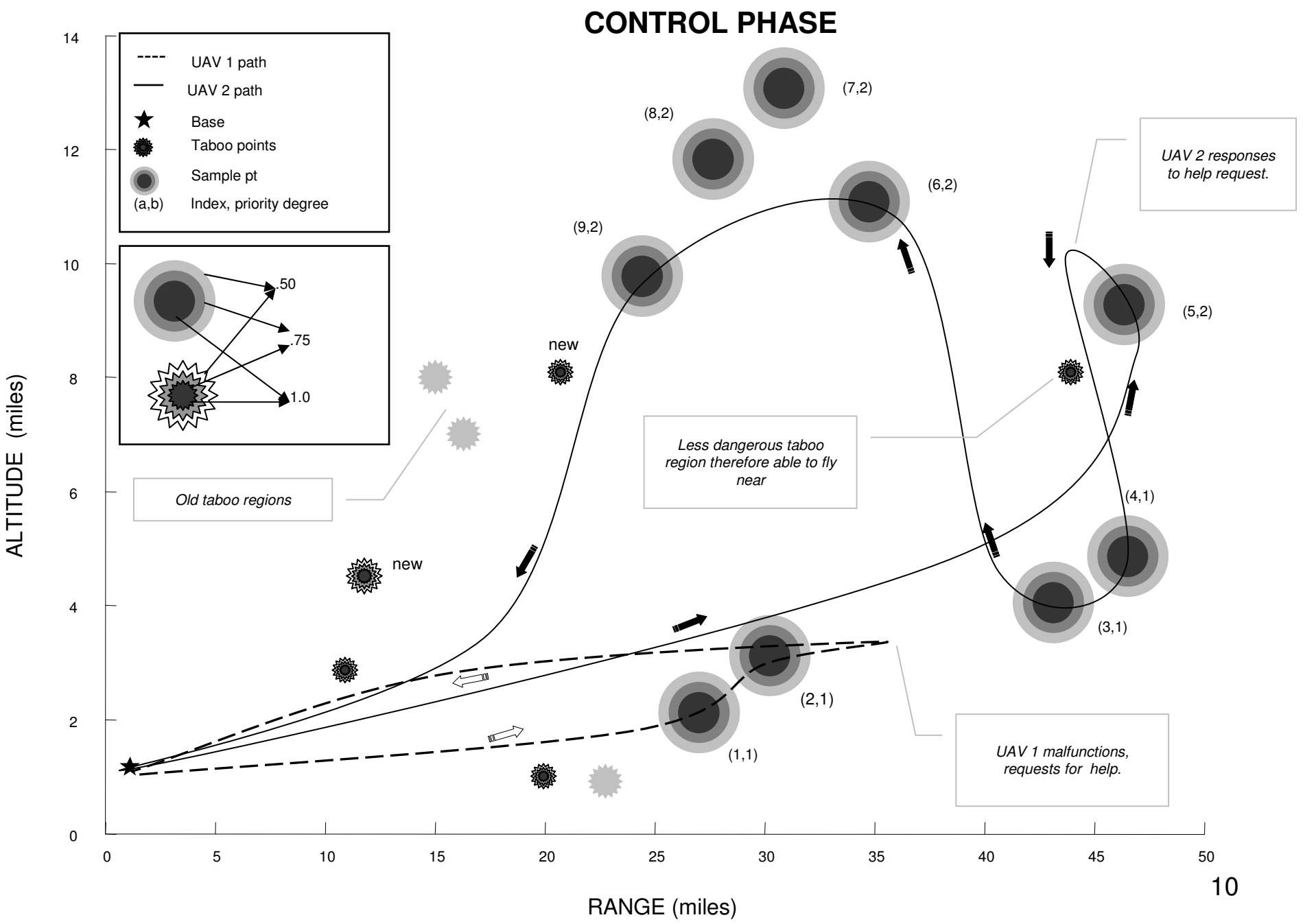
yellow dots = intermediate priority,

green dots = lowest priority


PLAN PHASE
X Plane
Y Plane
0
5
10
15
20
25
30
35
4,1
5,1
3,1
2,1
1,1
11,3
12,3
13,3
14,3
6,1
7,1
8,2
9,2
10,2
UAV 1 path
UAV 2 path
UAV 3 path
Base
Taboo Region
Sample pt
(a,b) Index, priority degree

Control Phase

- **Real-time control algorithm under development that allows**
  - new paths to be determined subject to changes in undesirable regions and regions desirable for sampling.
  - **UAVs** automatically cooperate through a priority scheme
    - **UAVs** automatically support each other if multiple regions must be measured to deal with extensive meteorological phenomenal
    - **UAVs** automatically support each other during times of malfunctions or suspected reductions in sensor or other system reliability


CONTROL PHASE
UAV 1 path
UAV 2 path
Base
Taboo points
Sample pt
(a,b) Index, priority degree
.50
.75
1.0
Old taboo regions
new
new
Less dangerous taboo region therefore able to fly near
UAV 2 responses to help request.
UAV 1 malfunctions, requests for help.
(7,2)
(8,2)
(6,2)
(9,2)
(5,2)
(4,1)
(3,1)
(2,1)
(1,1)
ALTITUDE (miles)
RANGE (miles)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
40
45
50

Priority for Providing Help

My priority for providing help is *.50*

My priority for providing help is *.75*

I have discovered an extended weather system. Please help sample it.

Fuzzy Decision Trees

- **Multiple Fuzzy concepts**
  - Risks
  - Resources
  - Mission Priorities
- **Decision trees and rules**
  - Assigning task load
  - Choosing helper **UAVs**

Post-Mission Phase

- **Simple linear MFP processor (SLMFP)**
- **Gradient MFP processor (GMFP)**
- **Extended linear array MFP processor (ELAMFP)**

Summary

- **Planning and control algorithms have been developed that allow multiple UAVs to facilitate the localization of electromagnetic sources using matched field processing**
  - **3 phases: plan , control and post-mission**
- **References**
  - **James F. Smith, III** and **ThanhVu H. Nguyen** "*Distributed autonomous systems: resource management, planning, and control algorithms*", proc. SPIE vol. 5809, p. 65:76, signal processing, sensor fusion, and target recognition XIV, 2005
  - **James F. Smith, III** and **ThanhVu H. Nguyen** "*Resource Manager for an autonomous coordinated team of UAVs*", to be submitted