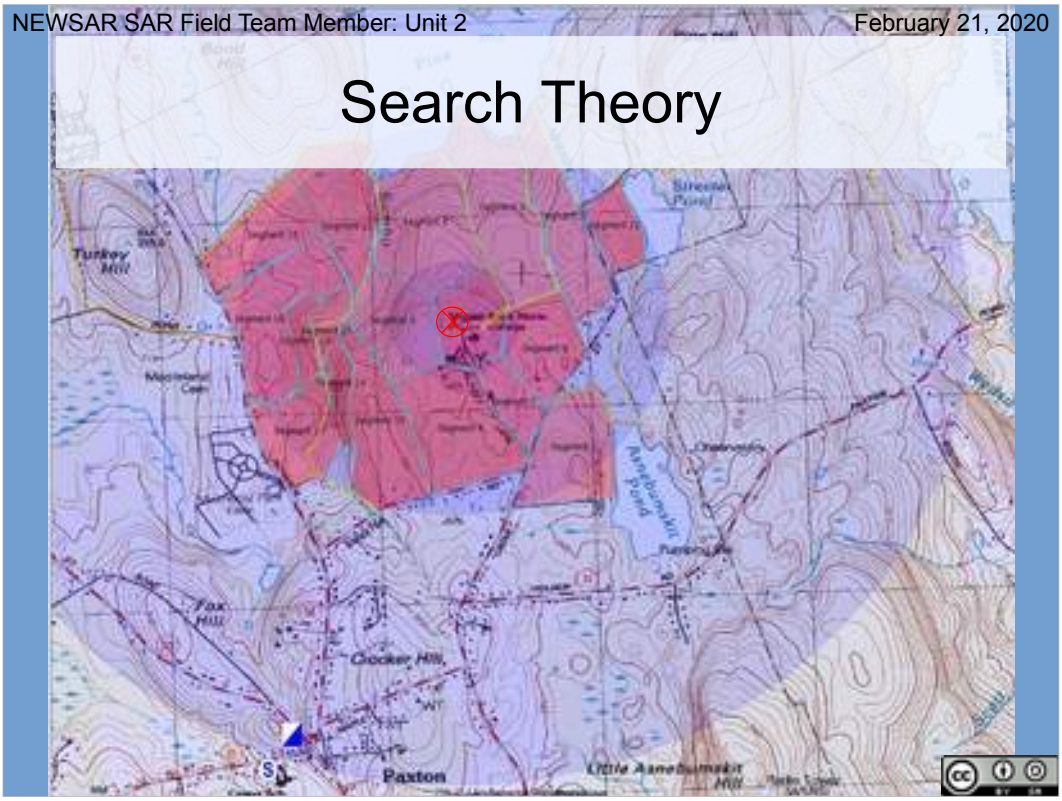
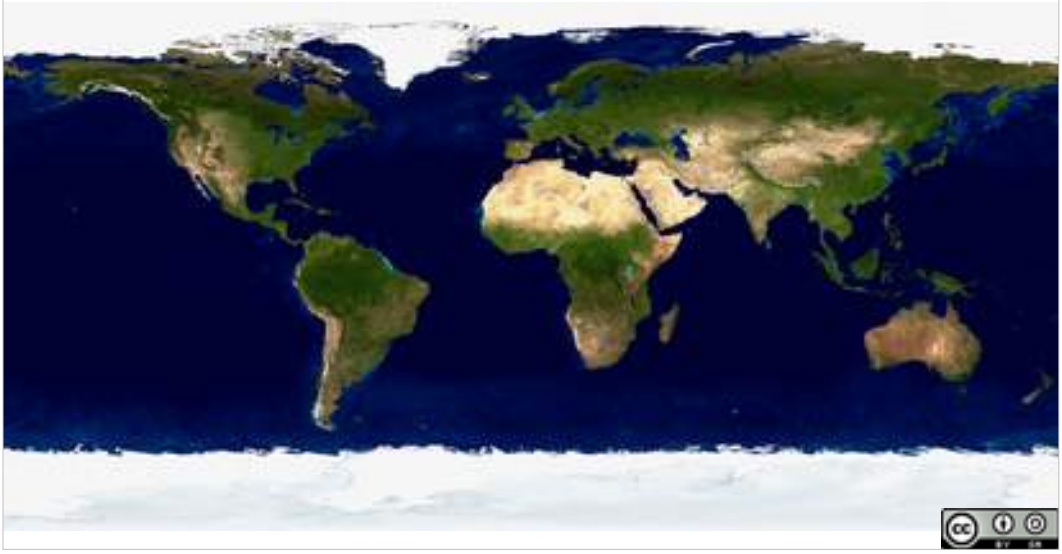


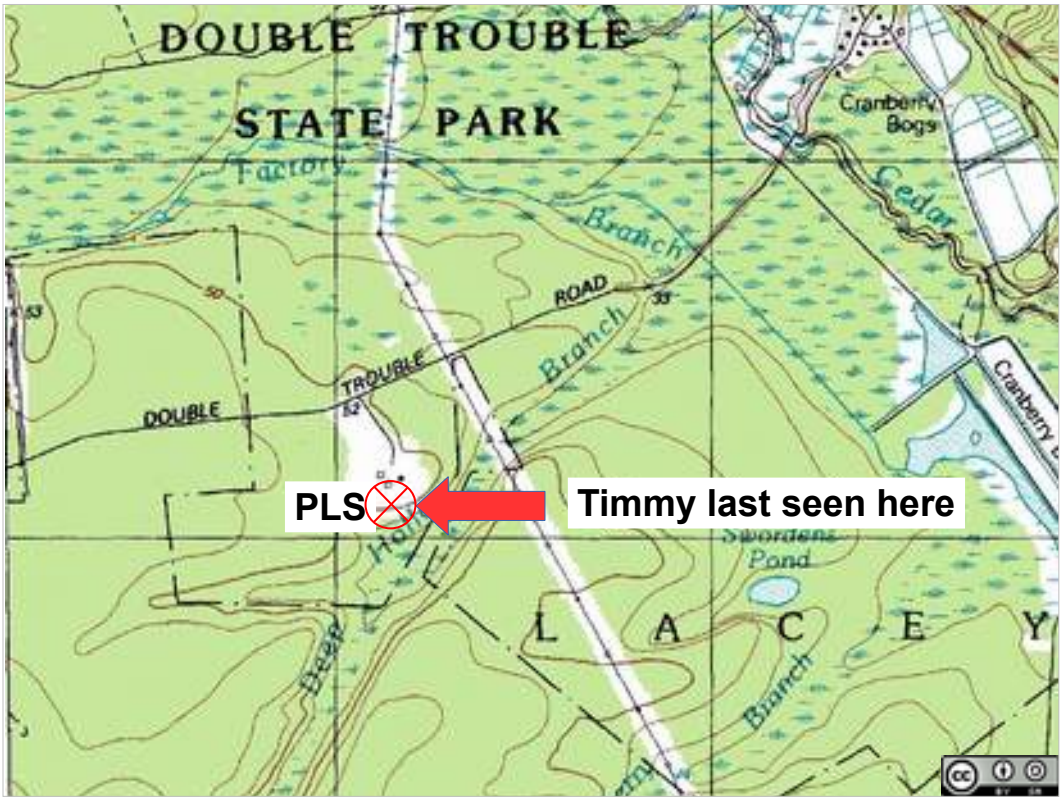
Unit 2: Overview of Search Theory.
Date Last Updated: February 21, 2020

Timmy is Missing



What do we need to know to start a search?

To put boots on the ground, investigation needs to determine where to search.



Timmy was last seen at a picnic area in Double Trouble State Park.

PLS

Point Last Seen

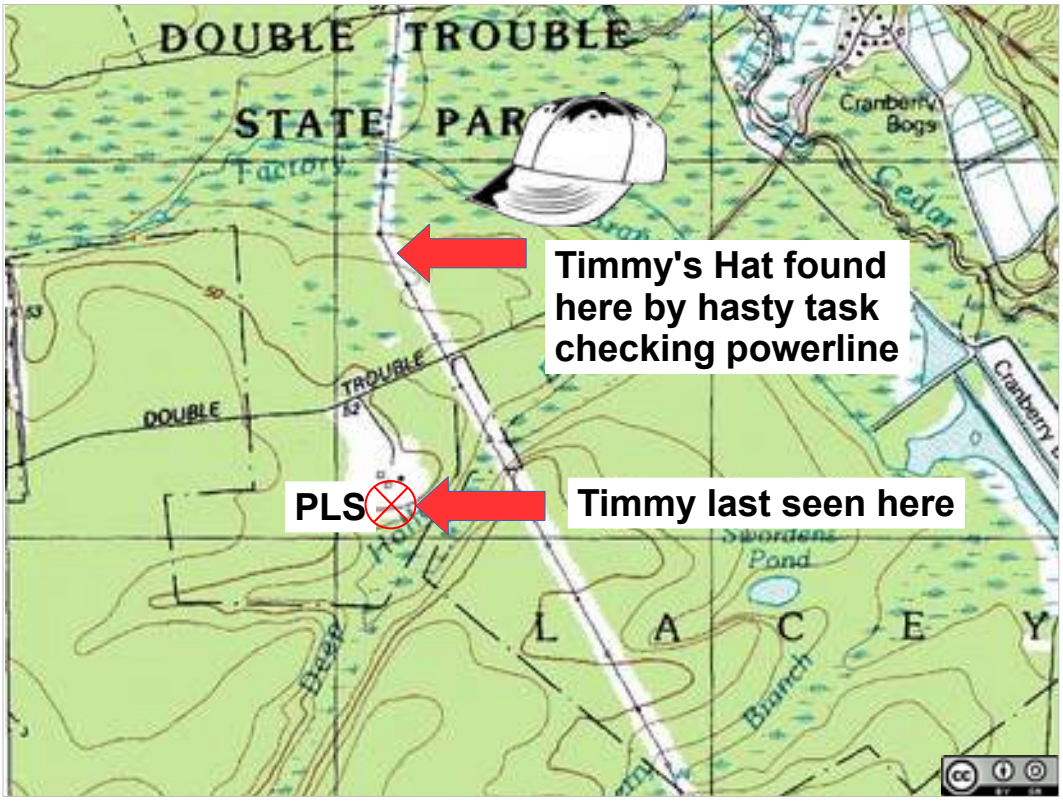
“The boys had been observed in the yard playing with a garden hose between 4:30 and 5:00 PM. Shortly thereafter, they were gone.”

Report of the Review Panel concerning the disappearance and deaths of three young young boys in East Camden June 22-24 2005.

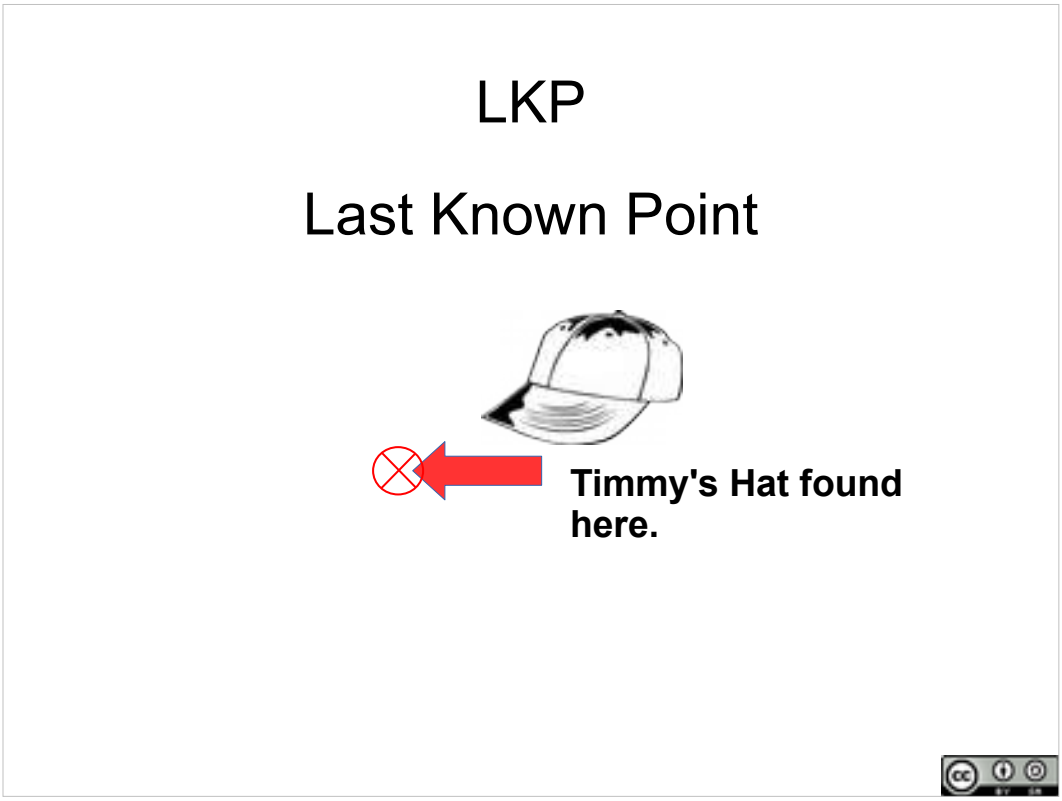
PLS: Point Last Seen

Place where the missing person was last reported as having seen by someone.

Can change over the course of a search (e.g. if the subject is seen by searchers).



Searchers are called out, run a hasty task along the powerline and find a hat that is identified as Timmy's.



LKP: Last Known Point

Location at which there is evidence for the subject having most recently been there.

Can change over the course of a search (e.g. discovery of a trail register with an entry by the subject, or with the discovery of clothing or equipment abandoned by the subject).

IPP

Initial Planning Point

PLS or LKP at the onset of the search.

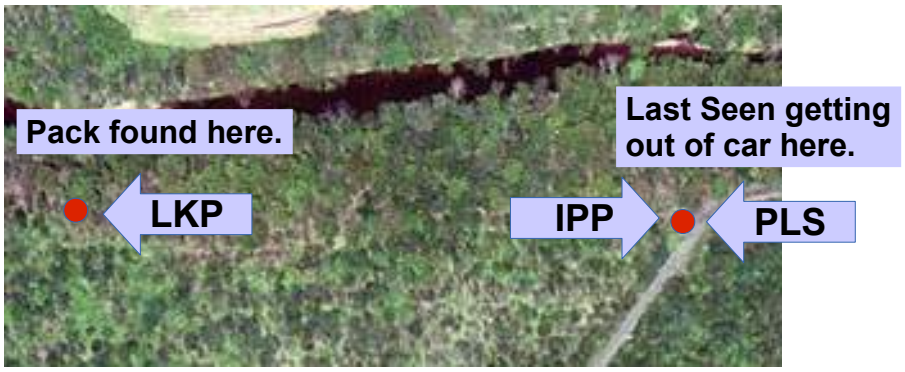
Never Changes

At the start of the search, the place where the subject was most recently known to be (whether it be a PLS or an LKP), is the Initial Planning Point.

The initial planning point remains fixed. Subsequent information may lead to new points last seen or last known points, and the focus of the search may change, but the IPP remains the initial planning point.

Lost person behavior statistics provide distances relative to the IPP.

- **PLS**: Point Last Seen
- **LKP**: Last Known Point
- **IPP**: Initial Planning Point

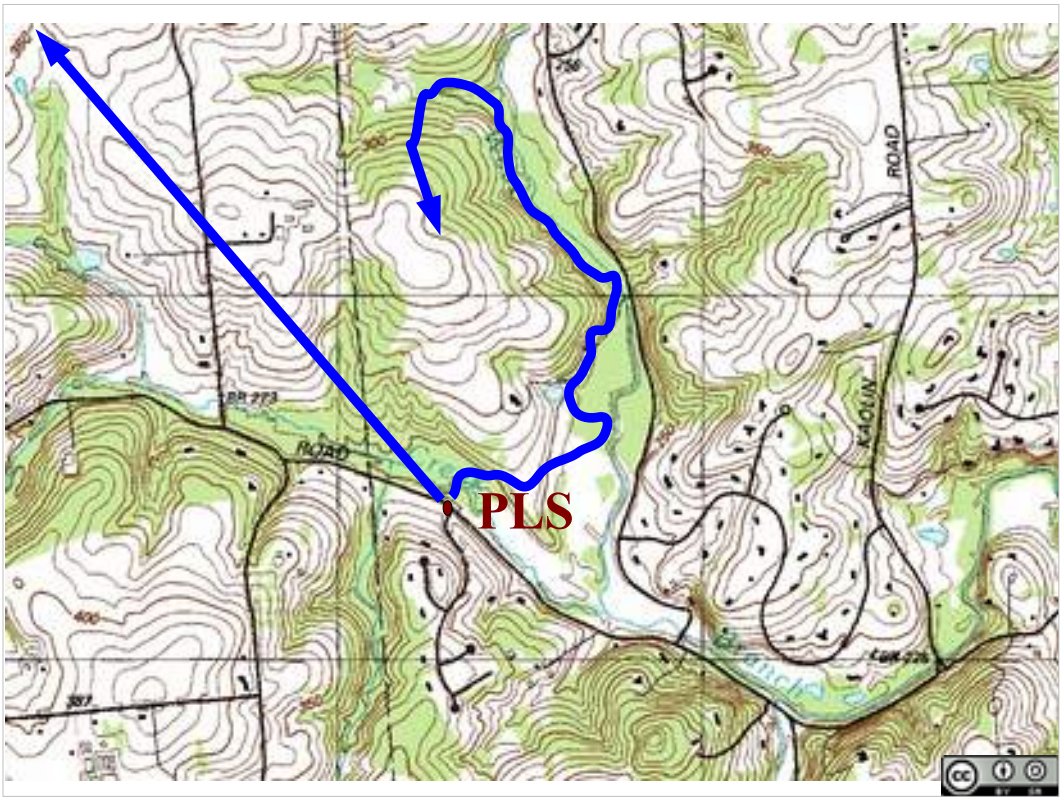


Reviewing, PLS,. LKP, IPP.

A person on foot can walk at 2-3 miles per hour.

The theoretical search radius is the distance that they could walk in a straight line in the time since they went missing.

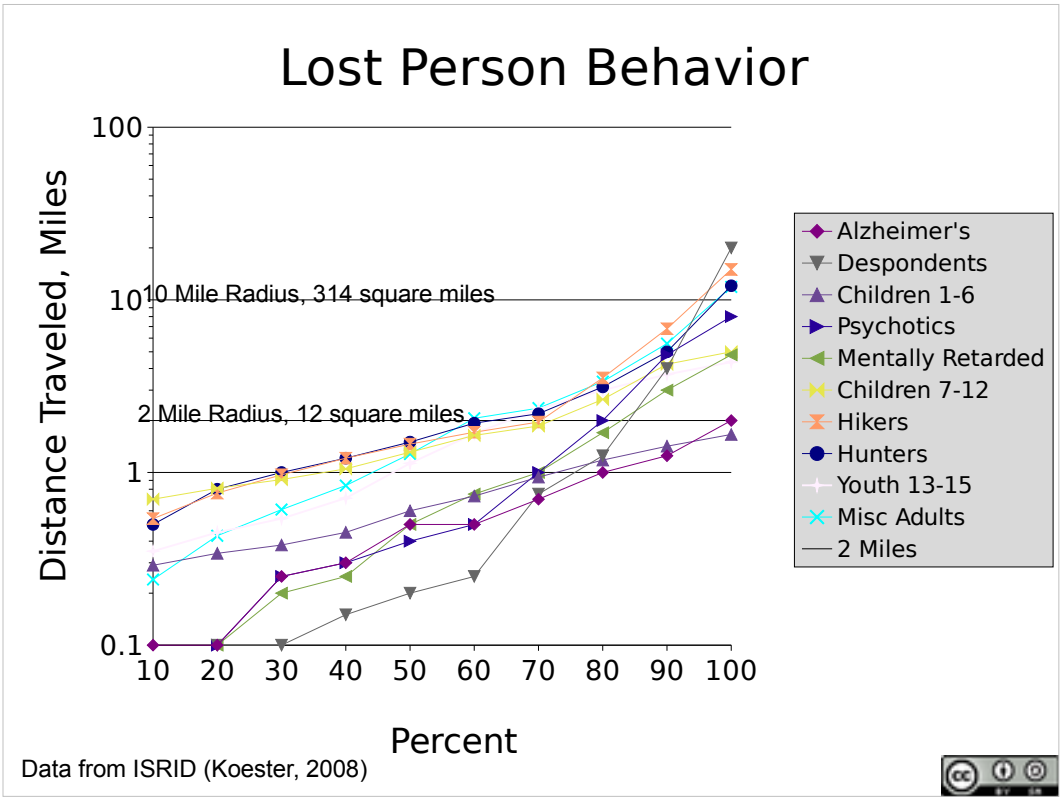
Theoretical search radius is just that – theoretical – the usual area within the theoretical search area is typically hundreds of square miles, much more than can be searched in a land search.



People don't travel in straight lines. Three miles per hour for 6 hours is not likely to be 18 miles as the crow flies.

Lost people, tend not to walk continuously in a straight line. They tend to meander and stop.

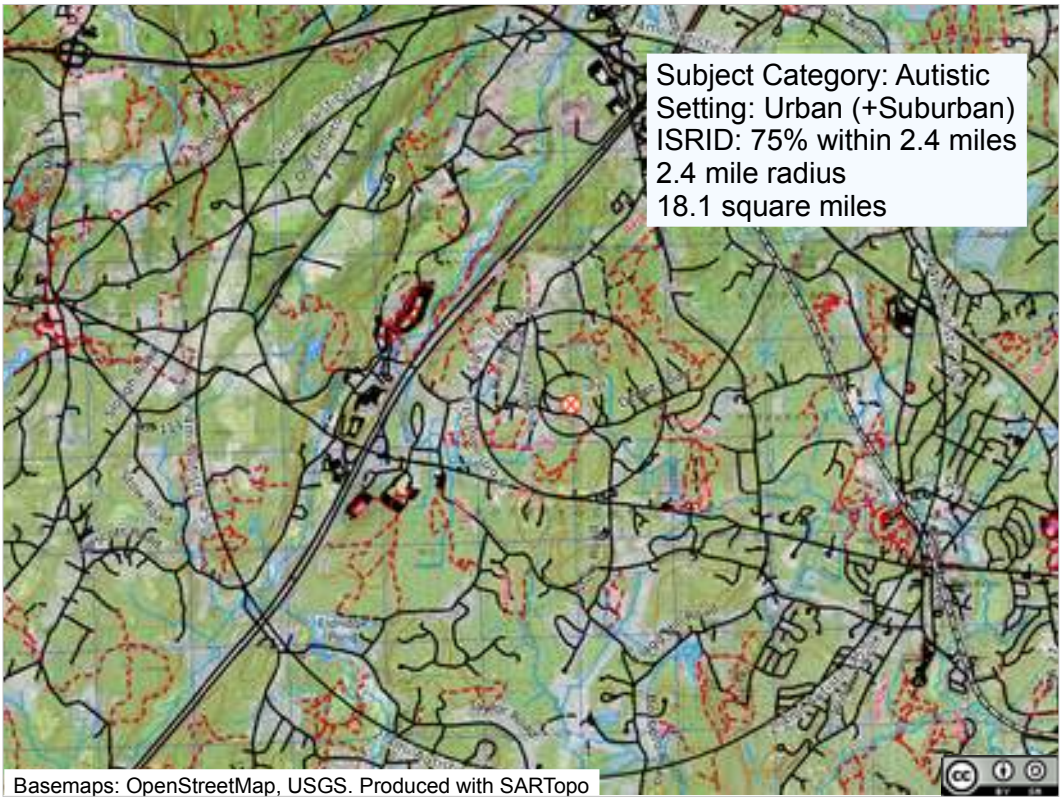
Terrain features can block, capture, and constrain the motion of lost persons in predictable ways.



Distance traveled varies by behavioral category. A very large portion of most lost person categories travel less than 2 miles from the IPP *(=12.56 square miles=8036 acres=134 60 acre segments).*

A small portion of a few categories (hunters, hikers, mentally retarded) travel more than 10 miles from the IPP.

Graph: x axis, percent of people in category found at the distance traveled (maximum at 95%). y axis, distance traveled from IPP (logarithmic, marked at 0.1 mile, 1, mile, 2 miles, 10 miles). Despondents: Gray triangle, 30% found within one tenth of a mile of IPP, 95% found within about 5 miles of IPP.



Let's pick a behavioral category: an Autistic subject.

In an urban/suburban environment, 50% of autistic subjects are found within 0.6 miles of the IPP. 75% are found within 2.4 miles of the IPP.

Predictable behaviors give us a statistical search area. The statistical search area is much more tractable than the theoretical search area (18 square miles, not 500-1000)....

Search Areas

- Theoretical
  - travel speed times time missing
- Statistical
  - how far do 75% or 95% of people in this missing person category travel?
- Deductive
  - Statistical, modified by terrain analysis.

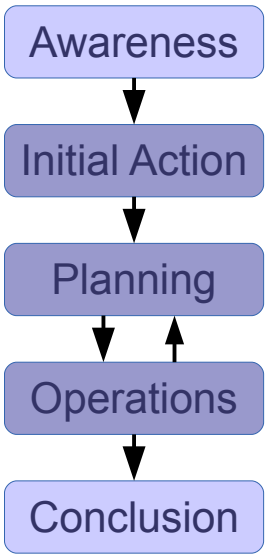
Theoretical search area is seldom practical or helpful.

Statistical areas required identifying a lost person behavioral category (investigation). 95% statistical distance for almost all categories less than 10 miles, 75% for all categories less than about 3 miles (about 28 square miles, or 18,000 acres, or 300 60 acre segments).

Deductive search area is statistical search area, modified by an analysis of the terrain (make smaller where there are travel barriers like large rivers, make larger where there are easy travel routes, etc).

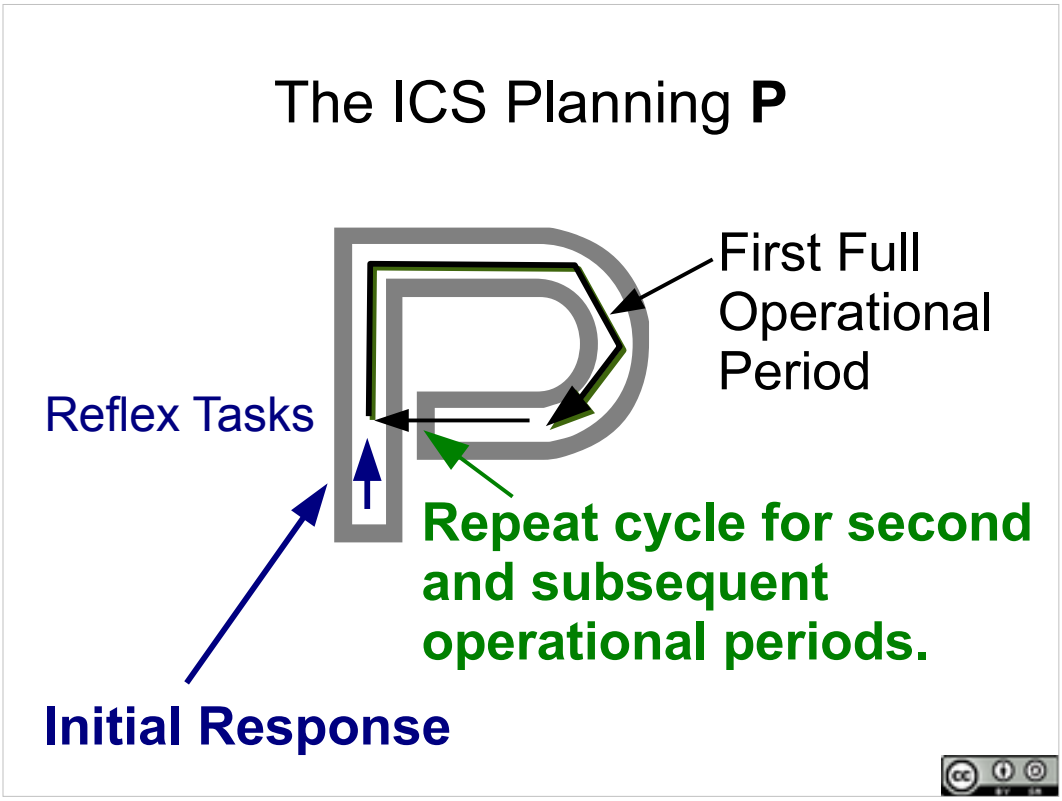
Still large: Search Crucial: Know if the subject leaves the search area.

IAMSAR Manual: SAR Stages



In unit 1, we described the 5 stages of a SAR operation listed in The International Aeronautical and Maritime SAR Manual

These are awareness leading to initial actions leading to cycles of planning and operations, and finally a conclusion.



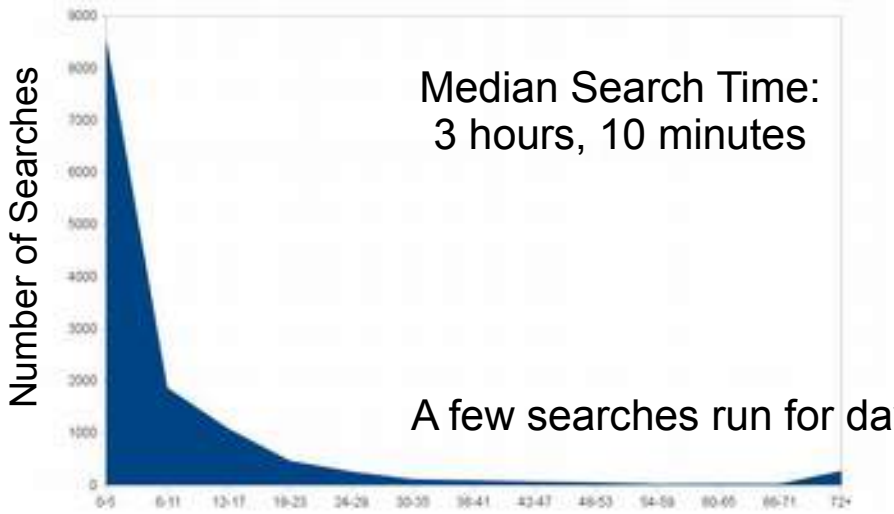
The Incident Command System has a concept very similar to the Initial Action + Planning and Operations Cycles: The planning P.

There is an initial response. In SAR, in the initial response we carry out reflex actions – hasty searches down travel routes, containment, securing the IPP.

Then, as the search extends beyond a few hours, it goes into operational periods that cycle planning and operations.

Initial actions should continue in parallel with the planning for the first full operational period (don't stop searching to plan).

Half of all searches are over in 3 hours



Data from ISRID: Koseter, 2008

Most searches are over quickly.

Half are over in 3 hours and 10 minutes.

A few searches run on for days.

Search Crucials

- **Search is an Emergency**
- **Search is a classic mystery**
- **Search for clues not just the subject**
- **Know if the subject leaves the search area**
- **Close grid search as a last resort**
- **Manage by objectives**
- **Search management is information management**

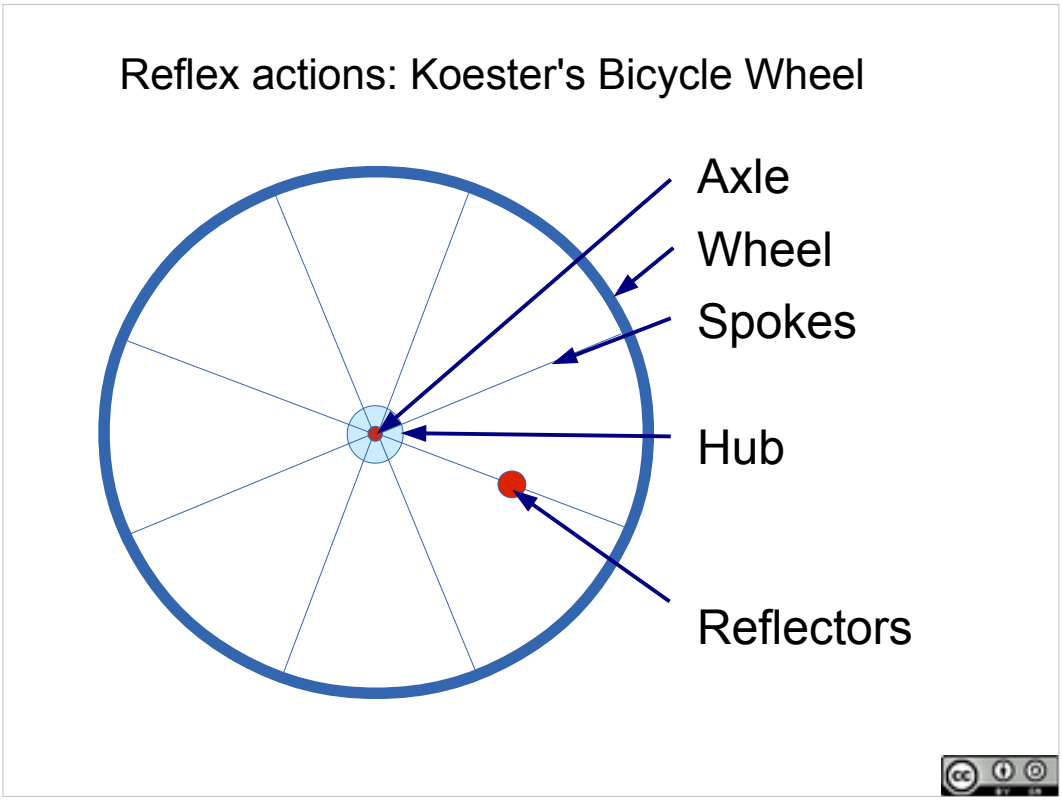
Initial Actions

- Classic mystery → Investigate
- Subject in search area → Confinement
- Emergency → Hasty Tasks
  - Areas of high risk
  - Areas of high probability
- Clues and the subject → Get Help

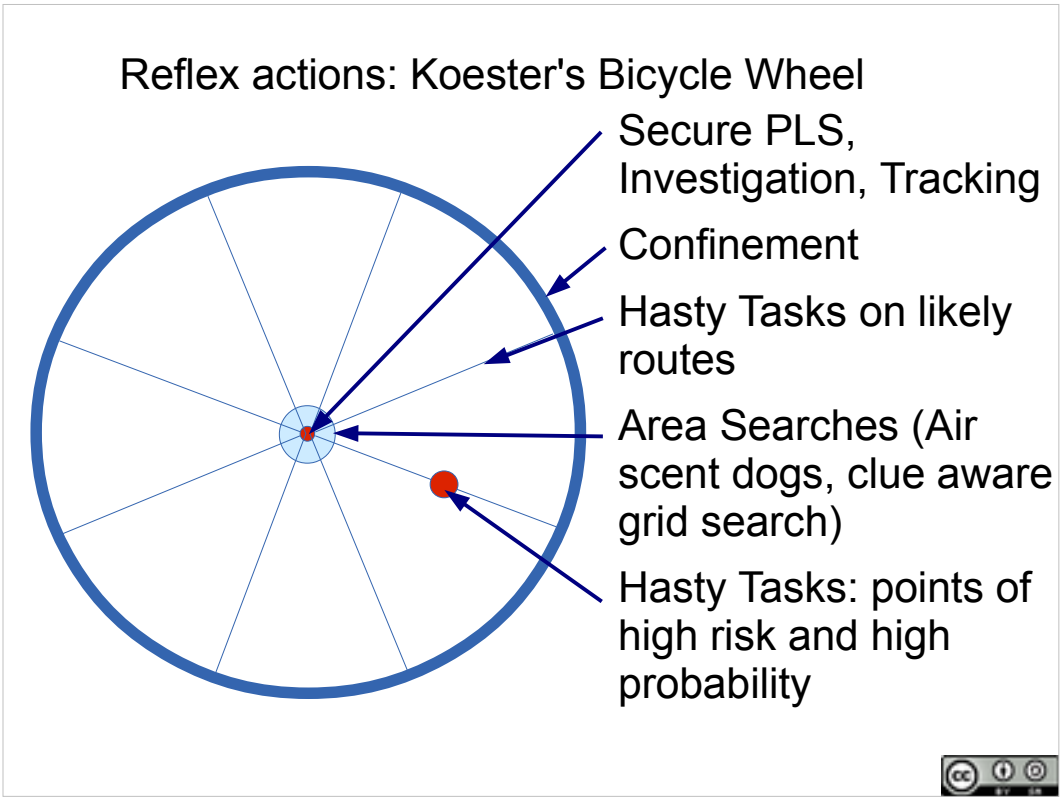
  Protect Clues
  - Secure the PLS
  - Scent Articles
  - Tracks

Flowing logically out of the search crucials are actions. Search is a classic mystery – investigate. Know if the subject leaves the search area – contain. Search is an emergency – search areas of high risk and high probability first. Search for clues and the subject – Protect the scene, protect clues, get help from specialised resources (dogs, mantrackers, search managers, etc).

Robert Koester came up with a powerful visual metaphor that can help you remember the set of systematic initial actions to take: The bicycle wheel.



A bike wheel has an axle, a hub around the axle, spokes that run from the hub to the wheel, the wheel itself, and reflectors.



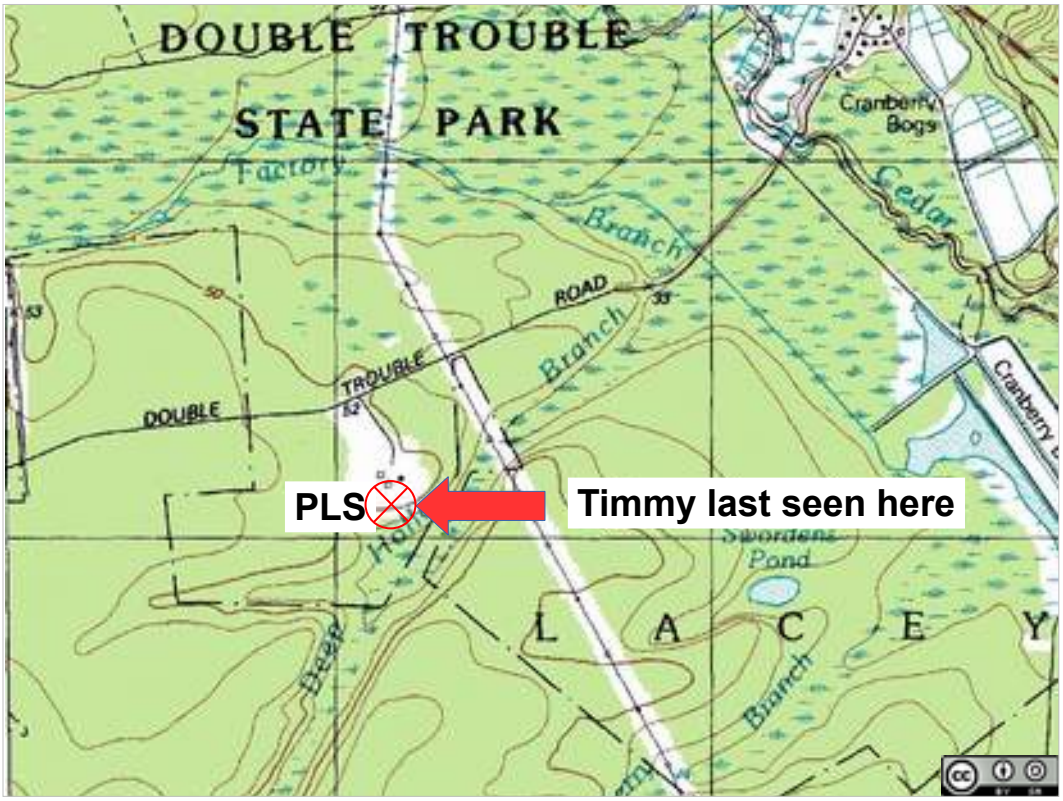
Axle: PLS – Secure it, investigation, resources that can provide a direction of travel.

Hub: Area searches in small area near PLS with high probability.

Spokes: Hasty tasks along travel corridors.

Wheel: Confinement – boundary to the search area - know if the subject leaves the search area.

Reflectors: Points of high risk or high probability – hasty tasks to check those points.

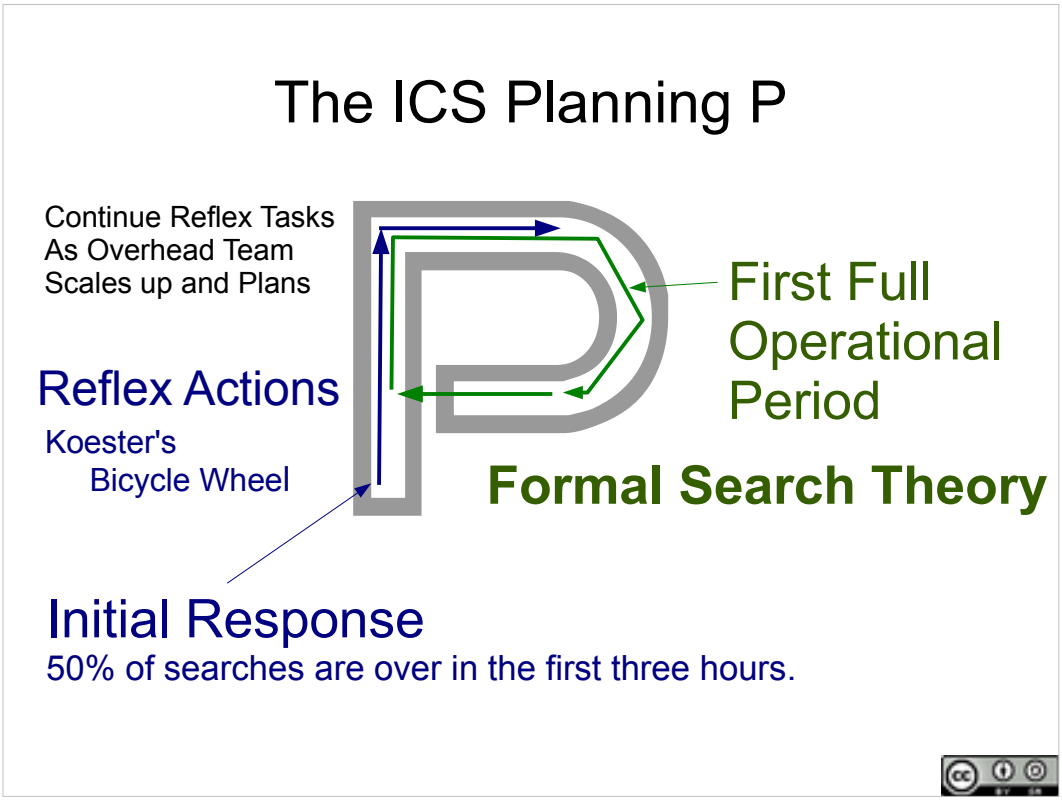


So, let's come back to the scenario: Timmy was last seen at a picnic area in Double Trouble State Park.

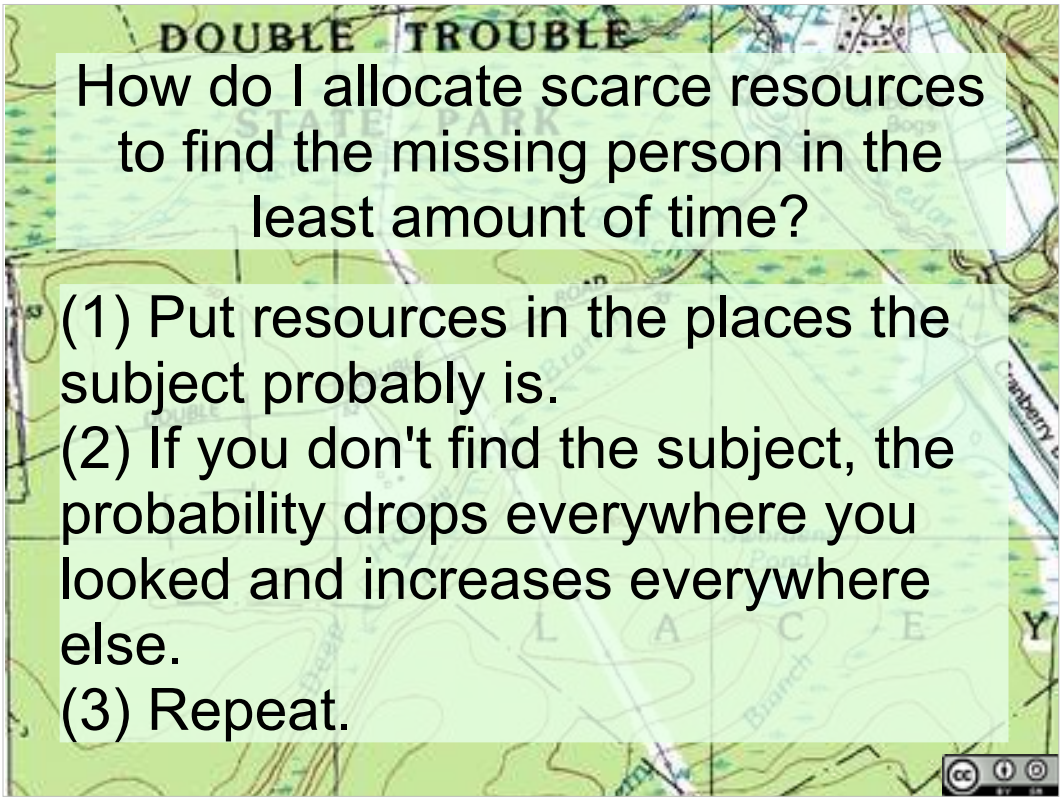
With Koester's Bicycle Wheel as a guide for Manage By Objectives, what objectives can we set for our initial/reflex actions?

Discuss.

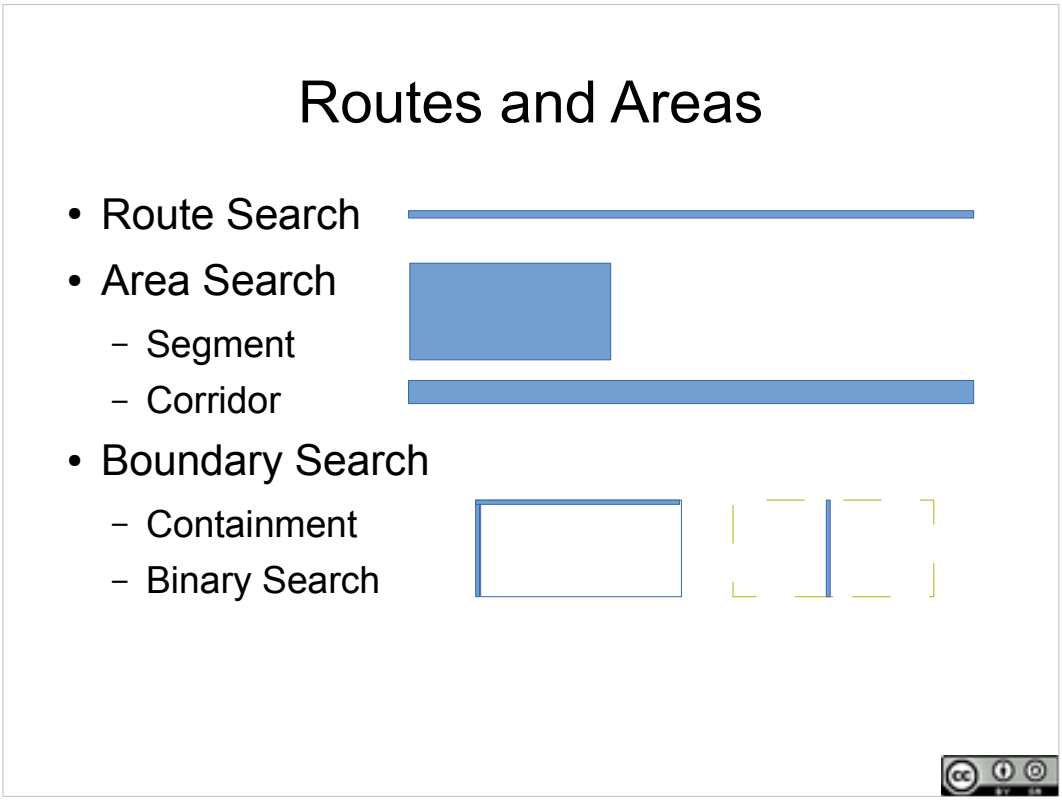
Tie proposals to axle, hub, spokes, wheel, and reflectors.



In SAR, we think of the initial response of the Planning P as these reflex actions (which make the find about half the time). Then, as the search moves into cycles of full operational periods, there is a shift from reflex tasks to a search planned with formal search theory.



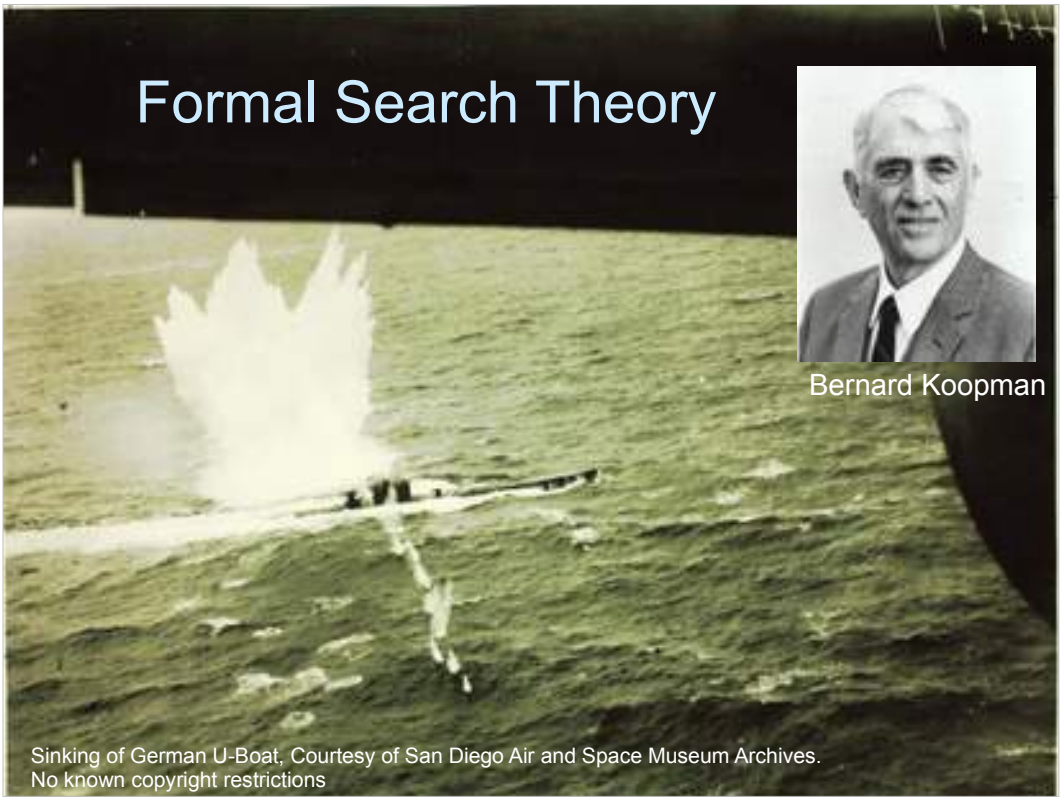
Formal search theory is all about resource allocation – where do we put limited resources to have the best chance of finding the missing person the soonest, and when you don't find them, shifting probabilities.



Oversimplified: Reflex tasking focuses on travel routes – which often have high probabilities, but there isn't a good statistical model of how to allocate resources to search travel routes. Formal search theory focuses on allocating resources to high probability search areas, then readjusting the probabilities as you search.

Formal search theory focuses on areas and probabilities.

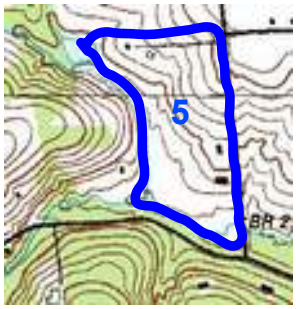
There are also search tactics (establishing a containment boundary in particular) that involve reducing the probability of a subject crossing some boundary without being observed (there are some formal models for detection on boundaries, but they aren't widely used in SAR).



Formal search theory comes from World War II, with Bernard Koopman's application of bayesian statistics to the problem of locating enemy submarines that were attacking convoys in the Atlantic.

POA: Probability of Area

- The estimated probability that the missing subject is inside some search segment.
- POA is estimated by experienced search managers combining models of where the subject may have gone.



POAs shift over the course of a search as segments are searched.

We start by assining a probability that the subject is in a search segment to each segment – Probability of Area.

A map of the search area is divided into segments.

Search managers go through a consensus process that simultaneously considers multiple scenarioes of what happened to the missing person to assign POAs to each search segment.

As a segment is searched, the POA in that segment drops and is shifted elsewhere.

POD: Probability of Detection

- Apply some sensor to some search segment
- POD is the probability that the sensor will detect the subject, if the subject is in the segment.

The sensor (task force) estimates its POD for the segment.

As each segment is searched, the searchers report a probability that they would have detected the subject, if the subject was in their segment.

POD – probability of detection.

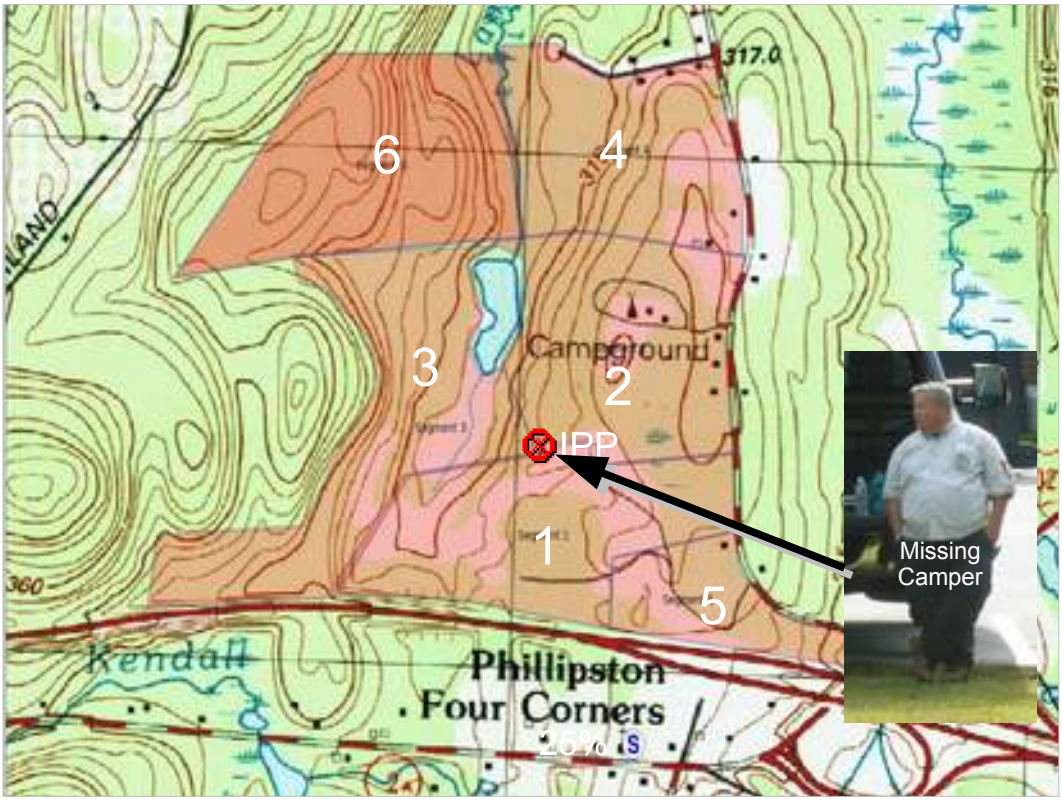
POS: Probability of Success

- Probability of finding the subject in a particular search. Estimator of search effectiveness.
- POS = POA x POD
- Implication: given some resources, search the segments with the highest Probability of Area to get the highest Probability of Success.
- Implication: Searching more area (more total POA) at a lower POD will yield a higher POS than searching less area more thoroughly

Formal Search Theory is about Allocation of Search Effort (Manage By Objectives)

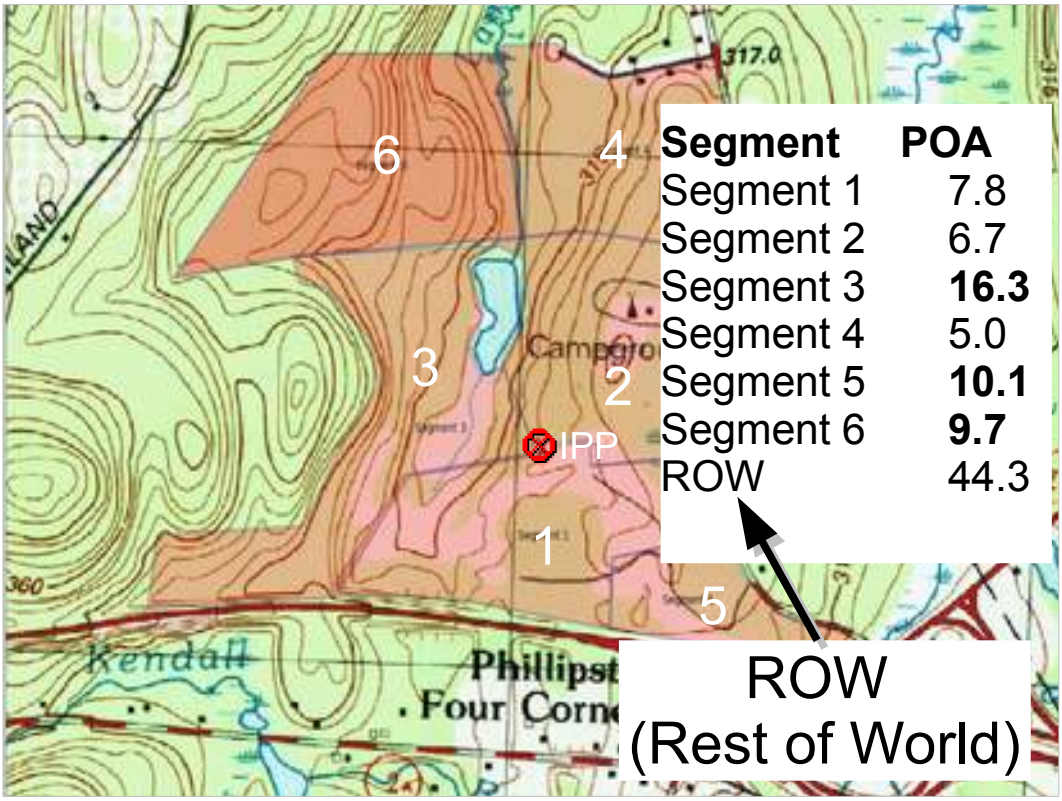
"For a given amount of available effort, there is an optimal effort allocation among the search segments that will produce the maximum OPOS [Overall Probability of Success]"

NSARC, 2011. LAND SEARCH AND RESCUE ADDENDUM to the National Search and Rescue Supplement to the International Aeronautical and Maritime Search and Rescue Manual. p. 5-17



So, let's consider a hypothetical search for a missing camper.

The area around the IPP has been divided into 6 segments (covering distance within which 25% of missing campers are found, and for this simple example, about half the area where 50% of missing campers are found (so we'd want more segments for a real search, but for this example we'll keep it to 6).



The search managers get together and estimate initial probabilities for each segment, leaving, here 44% of the probability outside the segmented area in ROW – rest of world.

For readability, we'll express all the probabilities here as percents (7.8% instead of a probability of 0.078)

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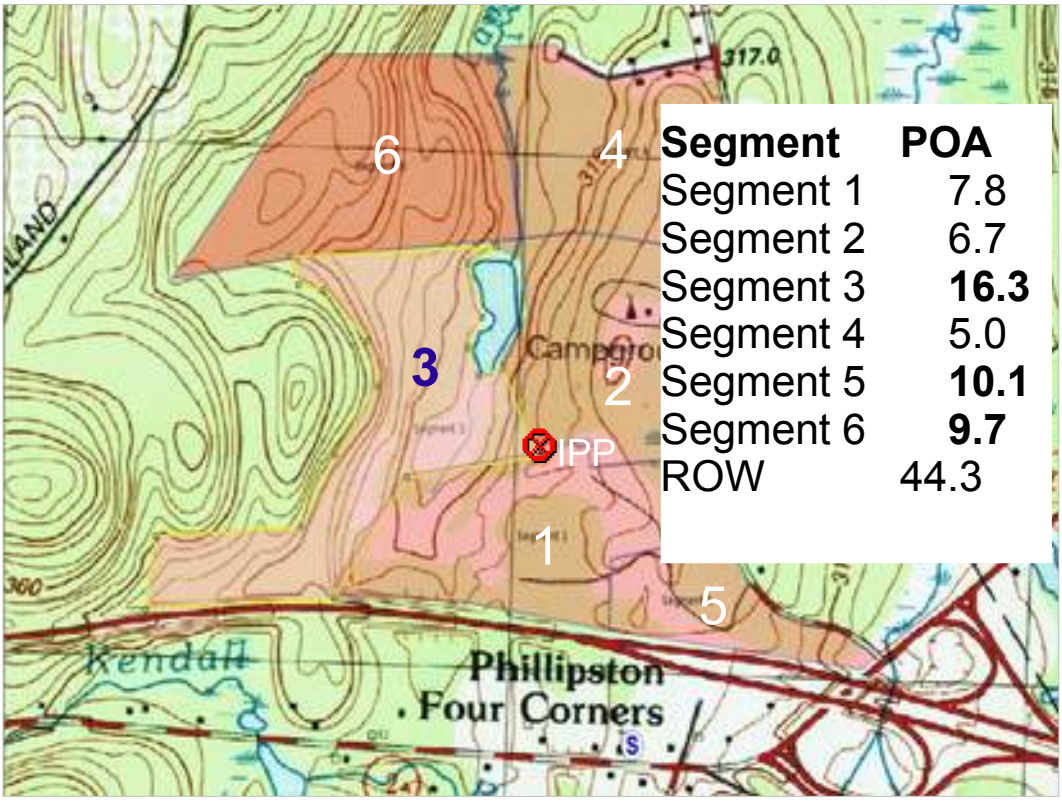
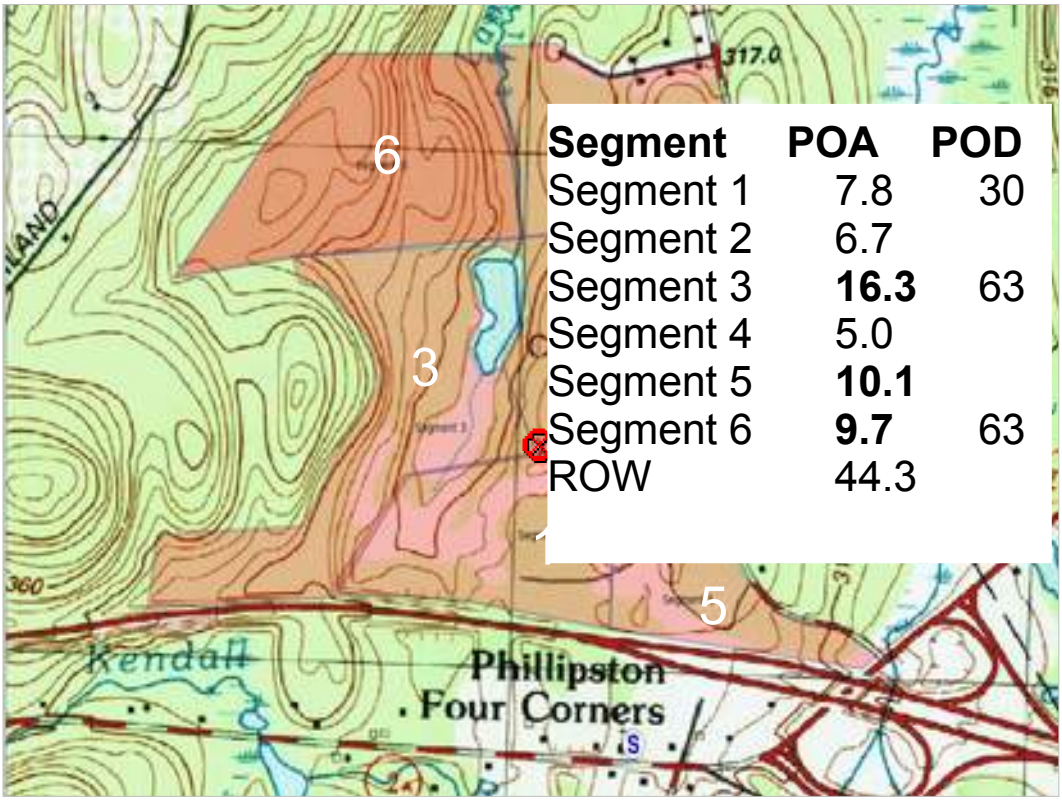
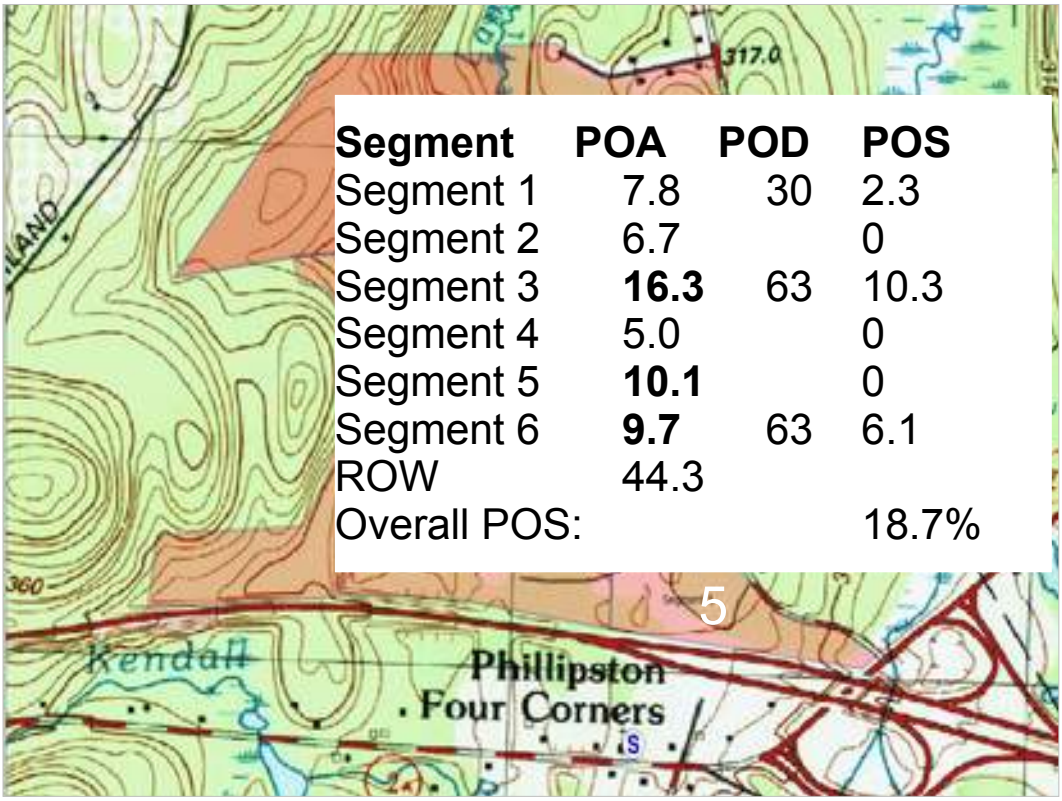


Segment 3 has the highest probability of area.



Segment	POA	POD
Segment 1	7.8	30
Segment 2	6.7	
Segment 3	**16.3**	63
Segment 4	5.0	
Segment 5	**10.1**	
Segment 6	**9.7**	63
ROW	44.3	

We put resources out to search segments 3, 6, and 1. They return and report probabilities of detection (of 30%, 63%, and 63%).

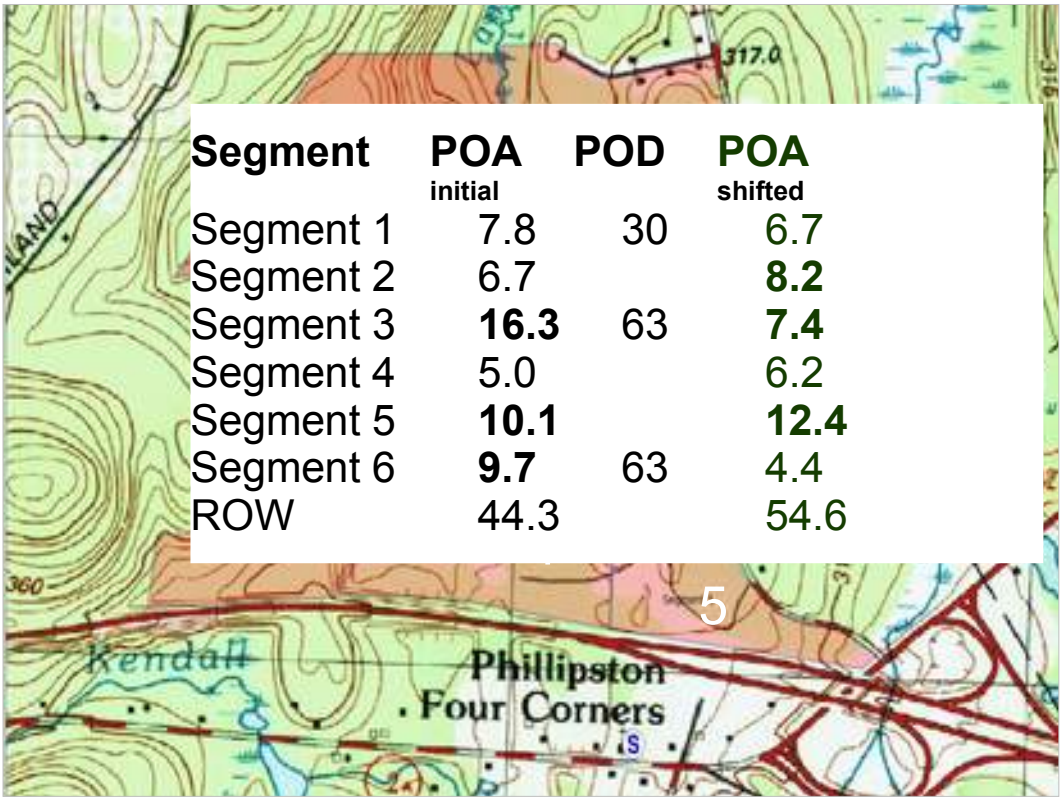


Segment	POA	POD	POS
Segment 1	7.8	30	2.3
Segment 2	6.7		0
Segment 3	**16.3**	63	10.3
Segment 4	5.0		0
Segment 5	**10.1**		0
Segment 6	**9.7**	63	6.1
ROW	44.3		
Overall POS:			18.7%

5

Then we can calculate the probability of success for this search effort: 2.3% for segment 1, 10.3% for segment 3, and 6.1% for segment 6. Segments we didn't search have no Probability of Success.

We can see how thinking about POS can help us plan resource allocation. If we'd put the resource used to search segment 1 into segment 5 and they'd reported the same POA, we'd have had a 3%POS for that segment. Segment 5 is smaller, than segment 1, so they might have had a higher POD, and an overall POS could potentially be 22.8% instead of 18.7%.

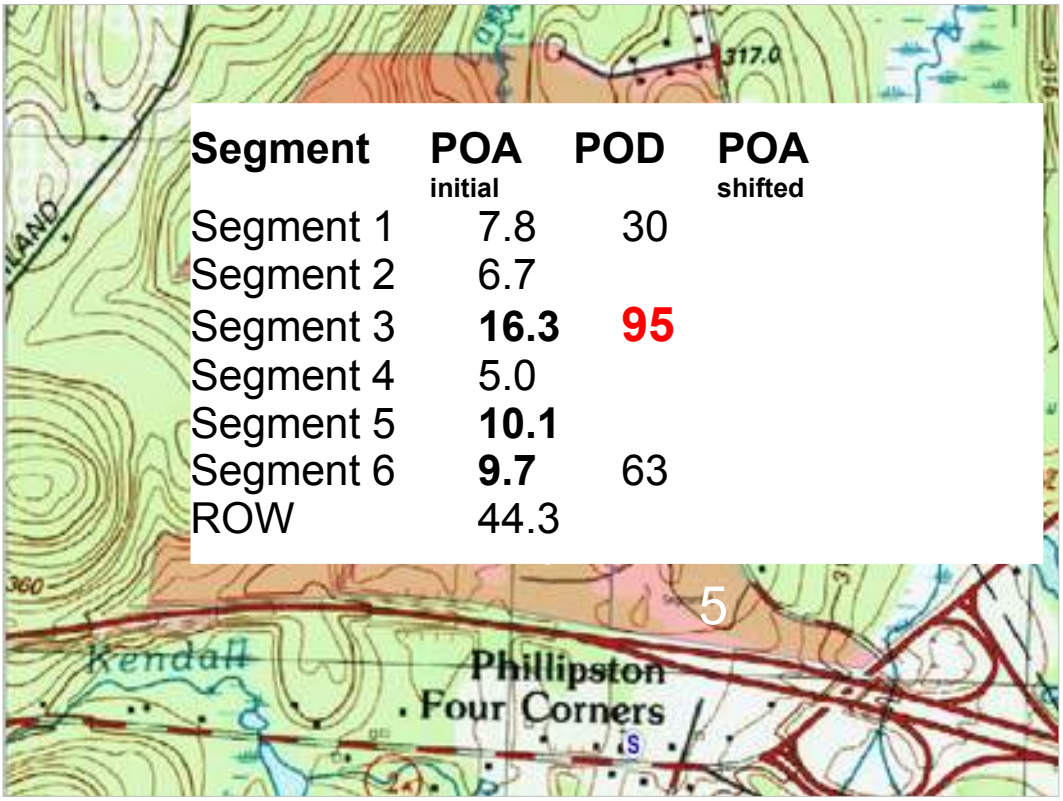


Segment	POA initial	POD	POA shifted
Segment 1	7.8	30	6.7
Segment 2	6.7		**8.2**
Segment 3	**16.3**	63	**7.4**
Segment 4	5.0		6.2
Segment 5	**10.1**		**12.4**
Segment 6	**9.7**	63	4.4
ROW	44.3		54.6

Now, we plug the numbers into a computer (there's a program CASIE that does this), and let the computer do the bayesian statistics to shift the probabilities around.

Where searchers reported a POD, the probabilities of area drop – and POAs rise everywhere else (including in ROW).

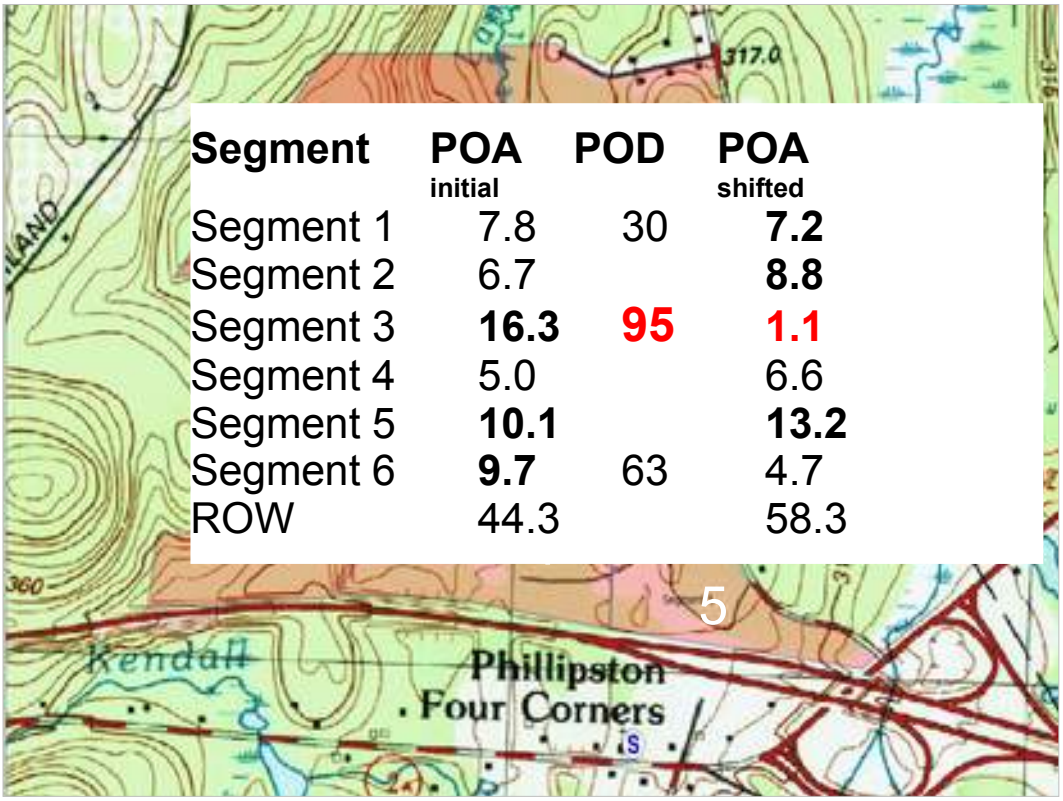
Top three segments are now 5, 2, and 3 – segment 3 is still very much in play.



Segment	POA initial	POD	POA shifted
Segment 1	7.8	30	
Segment 2	6.7		
Segment 3	**16.3**	**95**	
Segment 4	5.0		
Segment 5	**10.1**		
Segment 6	**9.7**	63	
ROW	44.3		

Now, let's suppose that the resource which searched segment 3 reported a 95% POD instead of a 63% POD.

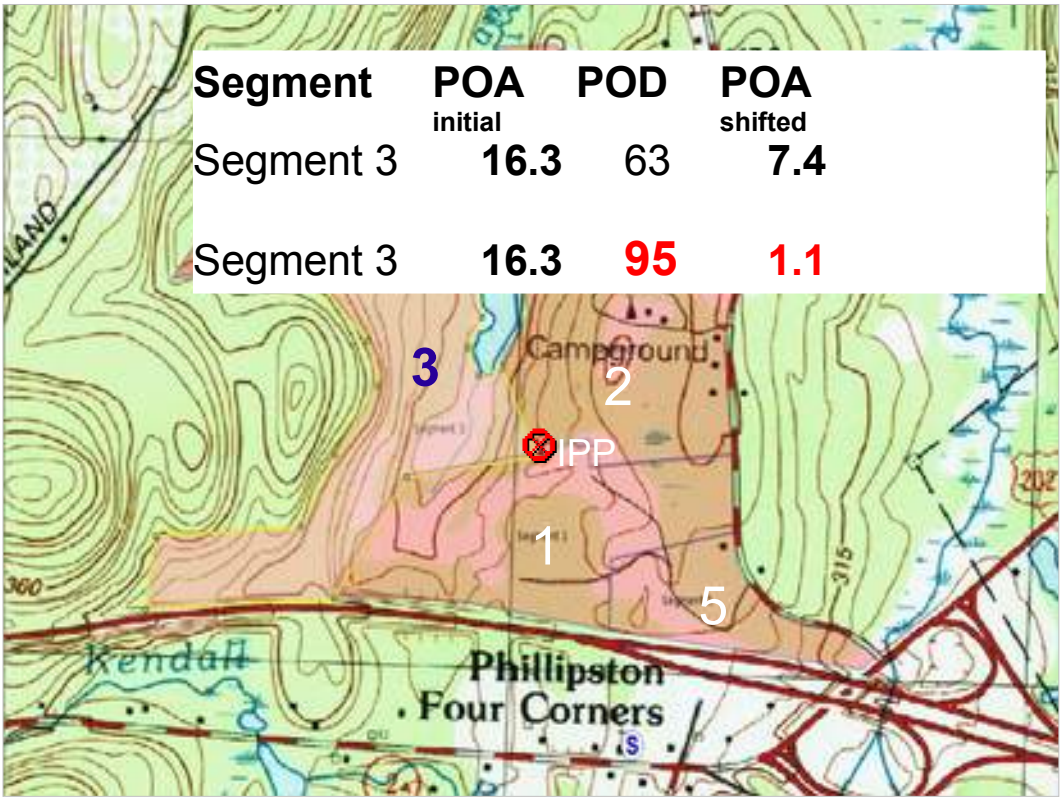
What is the consequence?



Segment	POA initial	POD	POA shifted
Segment 1	7.8	30	**7.2**
Segment 2	6.7		**8.8**
Segment 3	**16.3**	**95**	**1.1**
Segment 4	5.0		6.6
Segment 5	**10.1**		**13.2**
Segment 6	**9.7**	63	4.7
ROW	44.3		58.3

Shifted POA for segment 3 drops to the bottom of the list at 1%.

We aren't going back there for some time.



If the resource that searched segment 3 reported a POD of 63%, the POA for the segment shifts to 7%.

If the resource reports a POD of 95%, then the POA shifts to 1%.

Very hard to justify a very high POD – and it very strongly shifts the search effort away from a segment.

Don't use the word “cleared” - carries the implication of a POD of 100%. We never clear segments, we search them.

Excessively High POD reports Kill

Unless all Resources are reporting POD in a uniform way, the adjusted POAs that drive resource allocation are meaningless.

Simple phrase: Excessively high POD reports kill.

More subtle point: Unless searchers report uniform POD values for a given effort for a specific terrain the adjusted POA becomes meaningless.

Reporting POD is about precision, the same search effort for given conditions should result in similar reports for POD. We just saw the effect of the report from the search of one segment reporting a very high POD for the effort, relative to the reports of effort from other segments (a reported POD for segment 3 of 95% driving the POA down to 1.1%).

If two tasks spend about the same amount of time searching similar sized segments with similar ground cover, their reported POD values should be similar.

Learning More:

- NEWSAR POD/Canine POD course
- NEWSAR CASIE course
- NEWSAR Modern Search Management course
- NASAR Managing the Lost Person Incident

That's why NEWSAR has a POD course and trains search managers to use CASIE.

Search management courses:

NEWSAR: MSM

NASAR: MLPI

Search Crucials

- **Search is an Emergency**
- **Search is a classic mystery**
- **Search for clues not just the subject**
- **Know if the subject leaves the search area**
- **Close grid search as a last resort**
- **Manage by objectives**
- **Search management is information management**

Let's come back to the search Crucials.

Formal Search theory lets us use probabilities to help define objectives (broadly, how to maximize overall probability of success).

Thus: Manage by Objectives

Search is a classic mystery, Search for clues, know if the subject leaves the search area, all lead towards objectives.

Setting objectives lets us start thinking about the tactics to achieve those objectives.

Tactics

- Direct/(Active)

  Go find the subject.

  - Type I search (hasty/route search)
  - Type II to Type IV area search (human, canine, equine)
  - Aerial search

- Indirect/(Passive)

  Make the subject come to you/refine where to look

  - Investigation
  - Containment
  - Attraction
    - Sound
    - Lights
  - "Limited Continuing Search"

We can define search tactics as either Direct (or active) and Indirect (or passive).

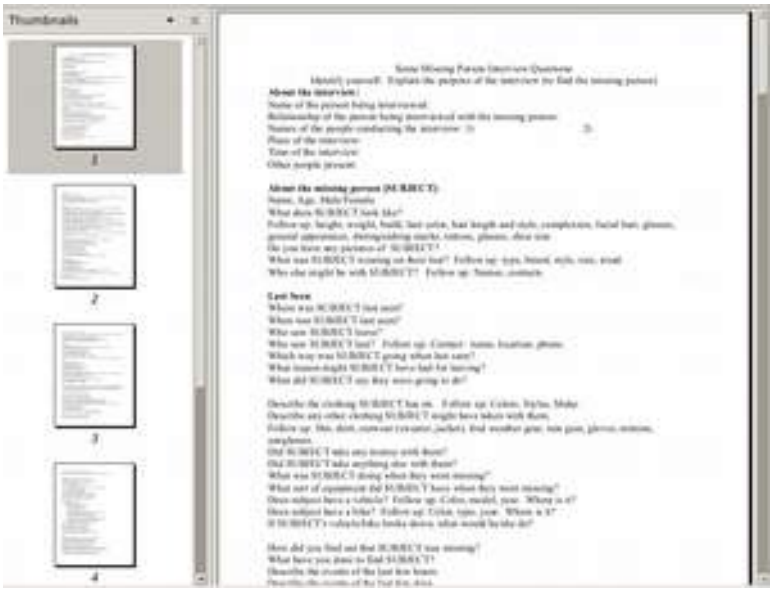
Here are some direct and indirect tactics.

Not mutually exclusive. Know if the subject leaves the search area – containment. Search for clues – direct route or area search.

Investigation key in all searches.

An Indirect Tactic: Investigation

An Investigation Tool: Lost Person Questionnaire



Function: Elicit Planning and Searching information.

Practical evolution 1.