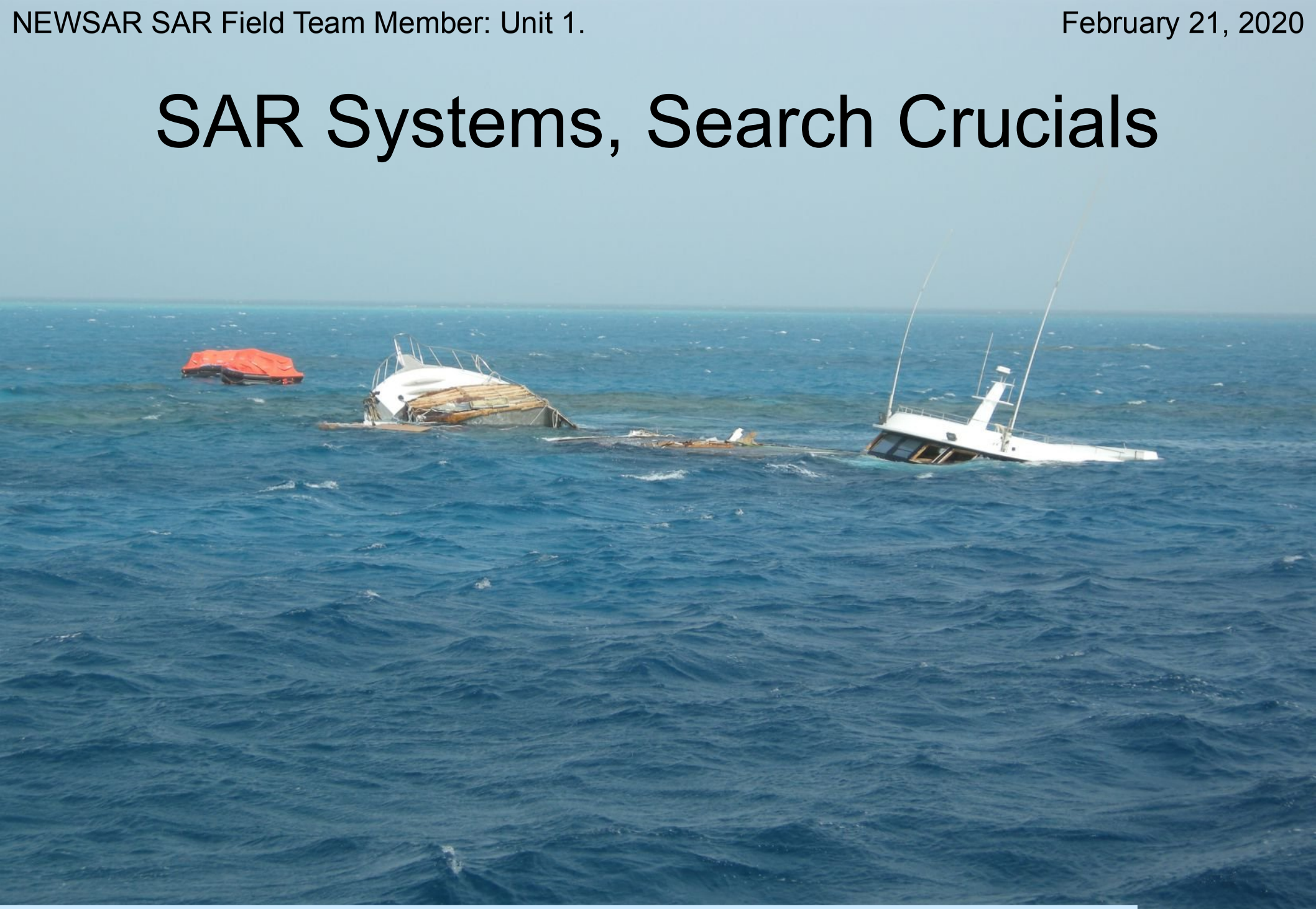
SAR Systems, Search Crucials



“Emperor Fraser hits reef and sinks near Dunraven”

NEWSAR SAR Field Team Member: Unit 1. February 21, 2020

SAR Systems, Search Crucials

"Emperor Fraser hits reef and sinks near Dunraven"

Unit 1: Overview of global SAR systems and introducting the "Search Crucials" - phrases that describe key elements of SAR.

Date Last Updated: February 21, 2020

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Search and Rescue

Search and Rescue

What's the difference? [Discuss]

Search and Rescue

- **Search**
  - **Locate Persons in Distress**
- **Rescue**
  - **Retrieve Persons in Distress**
    - **Access, Stabilize, and Transport persons in distress**
- LAST: **Locate**, **Access, Stabilize, Transport**

Two distinct concepts:

Search: looking for a subject who's location is not known.
Rescue: Stabilizing and bringing to safety a subject who's location is known.
(Or: Recovery: Retrieval of the remains of a deceased subject.)

Some SAR missions are purely rescue – the person in distress is at a known location and just needs to be brought to safety, most are primarily search with a much shorter rescue (or recovery phase).

An amplification is LAST: Locate (Search), Access, Stabilize, Transport (Rescue).

Maritime and Aeronautical SAR: International Agreements

- Convention on International Aviation
- International Convention on Maritime Search and Rescue
- SOLAS – International Convention on Safety of Life At Sea

  Parties agree to provide Maritime and Aeronautical SAR coordination and services
- Implementation in the US: NSARC: National Search and Rescue Committee.

SAR can happen anywhere.

There are international agreements concerning SAR for Air and Sea – in essence, governments have agreed to search for missing ships and planes in their territories, regardless of who is on board.

A (simplified example a) Panamanian flag ship in distress off the coast of India will be assisted by Indian authorities, and an Indian plane that crashes in Panama will be searched for by Panamanian authorities.

In the US, to oversee implementation, at the federal **cabinet level** is the the **National Search and Rescue Committee.**

Global Coordination

- ICAO: International Civil Aviation Organization
- IMO: International Maritime Organization

- Produce the IAMSAR manual: International Aeronautical and Maritime Search and Rescue manual (3 volumes, with national supplements).
- US: NSARC produces:
  - US National SAR Plan (Federal Inter-Agency)
  - US National supplement to the IAMSAR manual

Global coordination of SAR preparedness activities is through the international civil aviation organization and the international maritime organization – they produce the international aeronautical and maritime SAR manual. Individual countries produce national supplements laying out how they will fulfill their treaty obligations for aeronautical and maritime SAR.

In the US, the National SAR Committee produces a federal cabinet level inter-agency document, the US National SAR Plan that spells out at the policy level the responsibilities of **federal** departments and agencies in Maritime, Aeronautical, and Land SAR. US NSARC also produces the US national supplement to the IAMSAR providing implementation guidance to federal agencies (including the Land SAR Addendum to the US national supplement to IAMSAR).

Land SAR

- There is no international treaty governing land search and rescue within national sovereign territories
- Aeronautical SAR over land :Governed by the Convention on International Aviation
- The US National SAR Plan includes Land SAR responsibilities for Federal agencies.
- Key Agencies: DoD, USCG, FEMA, and the NPS (National Park Service)
- In the US, NIMS/ICS applies at all levels (local/ county/state/federal)

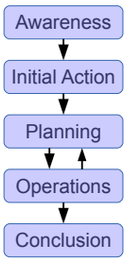
Land SAR is not governed by international agreements (except where planes are in distress on land).

The US National SAR plan, however, includes Land SAR responsibilities for federal agencies (in particular the National Park Service for SAR incidents on NPS managed land).

US Federal Land SAR missions may be Aircraft Missions, Distress Beacon Missions, or Non-Aircraft missions.

Lets look briefly at systems for maritime and aeronautical SAR

IAMSAR Manual: SAR Stages

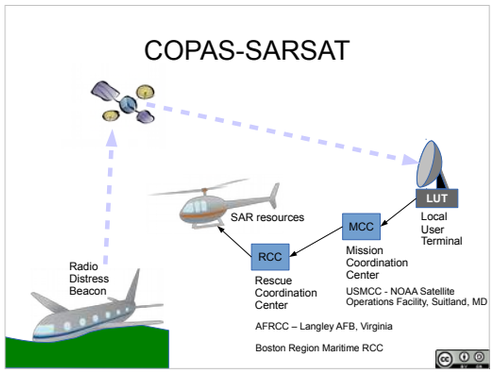


IAMSAR provides a broad picture of the process of SAR operations – dividing into Awareness, Initial Action, cyclical phases of planning and operations, and finally, conclusion.

LAST – locate, access, stabilize, transport – describes objectives during the planning/operations cycles.

Awareness of SAR incidents can come from distress beacons.

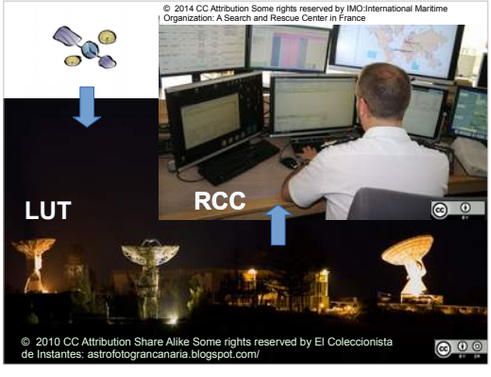
These are supported by a global network of satellites and grounds stations known as COPAS/SARSAT.



COPAS/SARSAT functions through transmission of a signal from a radio distress beacon.

Radio distress beacon sends out a signal, received by satellites, passed on to ground stations (Local user terminals), forwarded on to a MCC which deduplicates satellite signals, adds beacon registration information, and forwards to the appropriate (Rescue Coordination Center), which can then deploy resources.

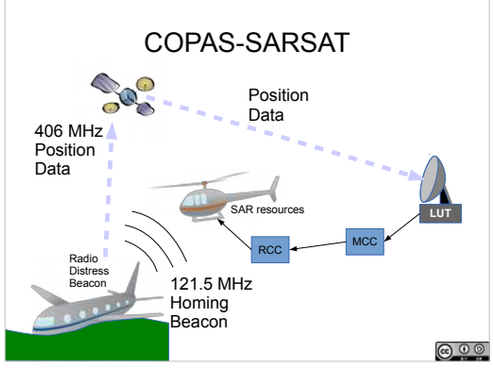
The radio distress beacon may not provide position data, and may need to be triangulated with several satellite passes.



Here's a LUT in the canary islands, and a RCC in france:

Distress beacon->satellite->LUT->MCC: Awareness phase.

RCC coordinates the remainder of the response.



Radio Distress Beacons transmit distress information for reception by satellites on 406 MHz, this can include GPS position data, depending on the beacon.

Radio Distress Beacons also transmit a homing signal on 121.5 MHz for direction finding by SAR resources.

Radio Distress Beacons

- PLB – Personal Locator Beacon
  - Manual activation
- EPIRB – Maritime – Emergency Position Indicating Radio Beacon
  - Activates when submerged in water
- ELT – Aviation – Emergency Location Transmitter
  - Activates on high G forces (sudden deceleration)

Several forms of Radio Distress Beacons that will trigger a COPAS/SARSAT response.

PLB – personal – manual activation.

EPIRB – maritime – activates when submerged.

ELT – aviation – activates on sudden decelearation.

Examples of EPIRB, ELT, and PLB.

PLB

Another PLB.

Personal Locator Beacons work with the COPAS/SARSAT system.

Non-COPAS/SARSAT SENDs

- SEND - Satellite Emergency Notification Device
- Like a PLB – Personal Locator Beacon
  - Manual activation
  - Can Include Non-Emergency messaging functions
  - Annual Subscription
  - Use Satellite Phone Communication (Iridium or GlobalStar)
  - Contacts a 911 center, rather than an RCC
    - Notification may not reach authority having jurisdiction
- SPOT, inReach, Spidertracks, Yellowbrick

There are also personal devices – SENDs (Satellite emergency notification devices) that can send out distress signals, but which don't use the COPAS/SARSAT system.

These use Satellite phone systems, have annual subscription costs, and may be able to send non-emergency messages as well as emergency messages.

SENDs contact a PSAP (public safety access point, a 911 center). The notification may not go to the authority having jurisdiction.

Non-COPAS/SARSAT SEND

"A SPOT Satellite GPS Messenger in a floation case."

An example of a SEND

Land SAR

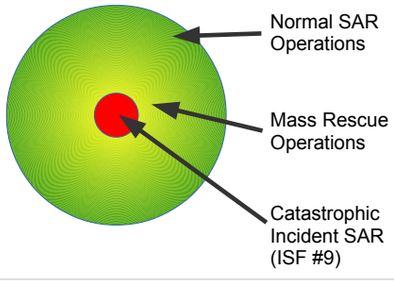
- Federal
  - NSARC: National Search and Rescue Committee
    - US National Search and Rescue Plan
    - National SAR Supplement to the IAMSAR manual
  - National Land SAR Coordinator: AFRCC
  - National Park Service (Lead SAR Agency in National Parks)
- State/County/Local
  - State SAR Plans
  - State/County/Local Authorities having Jurisdiction
- NIMS: ESF 9: Search and Rescue

In the US, Land SAR (other than aeronautical), is governed, at the federal level, by documents produced by NSARC: The US National Search and Rescue Plan, and the National SAR Supplement to the IAMSAR manual. These designate the AFRCC as the national land SAR coordinator, and the national park service as the lead SAR agency in national parks.

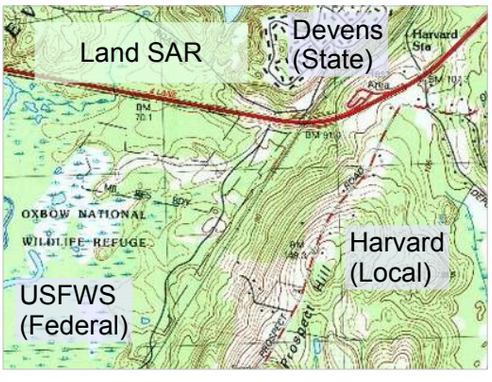
At the state/county/local level, there is substantial heterogeneity. State SAR plans may apply, pre-planning documents produced by state, county, and local authorities having jurisdiction may apply. In most of the country, the county sheriff is the authority having jurisdiction over land SAR incidents.

Under NIMS (in catastrophic incidents), SAR is Incident Support Function 9.

The Olive model for SAR incidents



NSARC introduced a model of SAR operations that draws a clear line (declaration of disaster or state of emergency) that separates catastrophic incident SAR operations (where NIMS and SAR as support function 9 comes into play), and other SAR operations which vary in scale and complexity from normal day to day operations to more complex mass rescue operations.



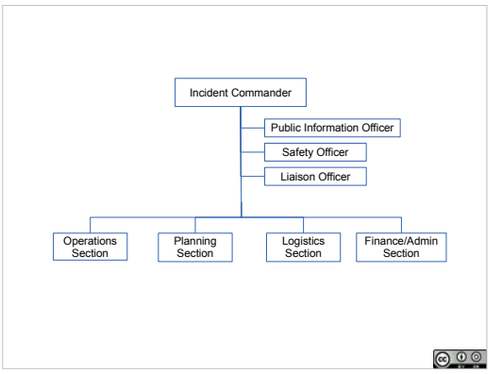
Even simple day to day SAR operations are complex.

They frequently span multiple jurisdictions.

Here, Town of Harvard, Devens (unincorporated, state police), Oxbow National Wildlife Refuge (DOI), just off the map, Towns of Ayer and Bolton, Devens Reserve Forces Training Area (DOD)...

MA State SAR Plan: Local authorities call out MA State Police, State police activate resources including volunteer SAR teams as resources.

NIMS: Use ICS.



ICS, The Incident Command System is the system under which Land SAR operations run in the US.

ICS provides a common management structure for incidents of all kinds.

ICS accommodates resources from multiple agencies and different jurisdictions. It is a language that all responders of all sorts speak.

ICS scales up and down with incident complexity.

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**

For many years, ERI has been teaching a series of short phrases that capture key ideas in land SAR.

We will return to these ideas multiple times in this course.

Let's see how these apply.

What does it mean to be lost?

[Discuss]

Lost

Missing

What is the difference between Lost and Missing?

Lost is from the subject's perspective – and will affect their behavior – if they feel lost they will behave like a lost person.
Missing is from family/friends/authorities/our perspective – the subject isn't where they should be and we don't know where they are.

[*Note: What follows is a sequence of scenarioes, asking lost or missing, highlighting each of the search crucials.* ***Bring out search crucials in discussion of each scenario on slides that follow.***]

Lost or Missing?

- Subject, uncharacteristically, stopped at a bar on the way home and stayed there late into the night.
- Wife, concerned that he hasn't come home dials 911.

He knows where he is – he's not lost.
She doesn't know where he is.
Classic bastard search.

Is this an emergency?

Yes – she dialed 911.
Yes – we don't know that he's not at risk.
Yes – Search is an Emergency

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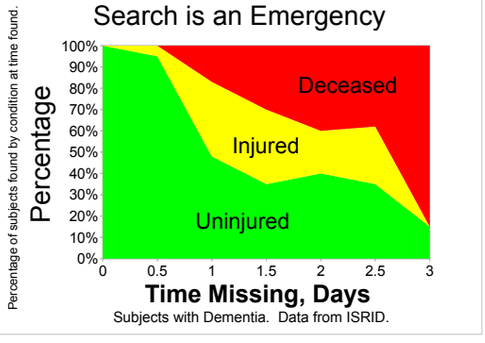
A search is always an emergency.

Search is an Emergency



For missing subjects with dementia, probability of a bad outcome increases substantially the longer that they are missing, with mortality increasing after 12 hours.

The data here are from ISRID, the international search and rescue incident database, compiled by Robert Koester.

Different categories of subjects have different probabilities. For example, children 1-3 have very high probability of surviving even after several days, while despondent subjects and subjects that abandon vehicles have much lower survival probabilities.

Note on the graph: The graph shows percent of uninjured/injured/deceased of the subjects found at 12 hour time increments (it isn't a survivorship graph, and the sample size decreases with time missing – thus more people happened to be found uninjured at 2 days than at 1.5 days).

Lost or Missing?

- 82 y/o female with dementia wanders out of her nursing home at some point during the day, drops her cane in a field across the road, and gets stuck in bushes 400 meters away.
- Her absence is noted at dinner, and at 8 PM the nursing home staff call for help.

Missing – the subject may not be aware that she is lost, though she will probably show characteristic behaviors of a critical elderly wanderer.

Dropped her cane – Had a cane – Mystery and clues – investigation can turn up that she had a cane. Clue aware searchers may find cane prints in the field (the subject left hundreds of clues), and may find the cane – leading them to the subject – search for clues and the subject.

Clue Log – key document

Search Crucials

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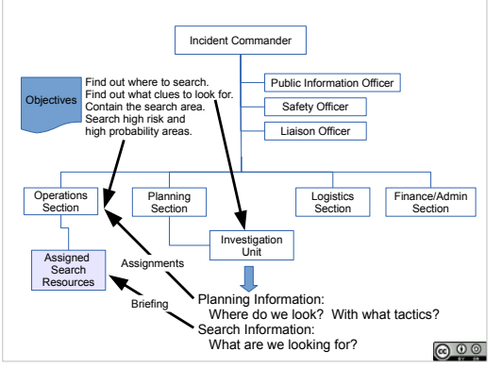
Search is a classic mystery – clues lead you to the subject, so you need to search for clues as well as the subject.

Thus, clue aware searcher.

What's this?

Sign – a print from a cane.

Clue aware searchers need to observe it, know that it is a potential clue, and transmit it back to the overhead team.



Command function sets the objectives, investigation function elicits planning information (where should we be searching, what sort of tactics should we be using), and searching information (what does the subject look like, what sort of clues might they leave behind (subject walks with a cane), what are the searchers looking for). Planning information and objectives feed into resource assignments made in the operations section. Search information gets fed to the assigned search resources (the field searchers) in briefings (subject walks with a cane).

The investigation function **may** be carried out by an investigation unit within the planning section.

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IC makes investigation an objective, cane can be elicited. ICS is key for managing disparate resources from different agencies – using them effectively means the IC setting objectives for the operational period.

Information about cane needs to be recorded, and make it into the briefing for search teams, and discovery of cane print as a clue needs to get recorded (clue log) and followed up on. Search management is heavily about information management (cane might not have been written down from interviews, might not have been included in briefings, might not have been reported, might not have been logged and followed up on).

Lost or Missing?

- 26 y/o male day hiker takes a wrong turn at a switch back, ends up in the woods over the ridge, can't find the trail, bivouacs for the night, then continues hiking down a drainage in that valley the next morning.
- Family reports him overdue the first evening.
- His car is located at the trailhead.
- A party camping at a lean-to in the trail system, reports seeing someone matching his description on the trail that day.

Lost and missing.

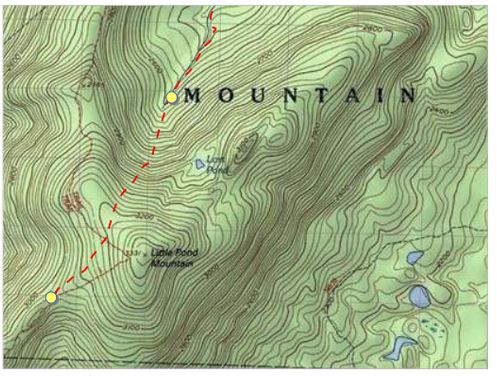
Probably behaving like a missing hiker. Hiker, may just keep moving – contain the search area.

Car and report are clues pointing to where to search (trail, and areas hiker may have lost the trail). Clues may be information elicited by searchers questioning people they encounter.

Switchback is a typical decision point where people make mistakes. Sending a wilderness air scent canine task up the drainage in the valley past the switchback is a very plausible task emerging from investigation and knowledge of lost person behaviors.

Close Grid search very unlikely to help locate subject.

Initial tactics include resources that can cover large routes quickly (e.g. mountain bikes on the trails, air scent canines on likely travel routes).



Map

Subject following the brown trail.

Subject takes a short cut through a switchback at the bottom yellow point.

Anticipated travel from the decision point is the red line, missing the trail, going over the ridge, getting sucked into the drainage. Find at upper yellow point.

Air scent canine task up the valley is a logical task to consider.

Search Crucials

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Search is a mystery – you need to elicit information to solve it.

There are many more clues than subjects – look for clues that can lead you to the subject.

Contain the search area – subjects may keep moving, making the search area grow and grow.

Missing persons are likely to cross trails and roads and just keep going in what they think is the right direction.

Lost or Missing?

- 42 y/o hunter follows wounded game, becomes disoriented and unable to find his way back to his car. Following folklore, he goes down hill to a stream and follows it (away from roads into dense brush), where he falls and breaks an ankle on a rock.
- That night, his wife reports him overdue.

Lost and missing.

Behaving like a lost hunter.

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Route search resources along likely travel corridors. For example, wilderness air scent canine resources working drainages.

Many categories of missing subjects may be anywhere within a large search area (of many square miles – close grid searching is very inefficient resource intensive – most of the time start with efficient tactics that are more likely to locate the subject with fewer resources.

Close grid searching is also destructive – efficient, clue aware resources are more advantageous most of the time.

Lost or Missing

- Toddler disappears from family picnic in backyard. Family calls 911 within minutes.
- Police, Fire department, ambulance, neighbors show up on scene in minutes.
- More firefighters and Police with canine from neighboring jurisdiction on the scene about 15 minutes later.
- State police and helicopter on scene about 10 minutes after that.

Missing. Too young to have a sense of lost.

Very likely to be close by, curled up in a hollow log, under dense brush, etc, not responding to searchers.

Exception that proves the rule – some categories of missing person don't travel far, and grid search of area immediately around where the person in these categories went missing has a high probability of locating the subject.

Rapidly expanding incident, multiple resources with different command structures from different jurisidictions – recipe for chaos – Use ICS, manage by objectives – It's 13:30, by 14:30, have thouroughly searched area within 300 m of back yard, looking in all spaces where child would fit.

Search Crucials

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- **Close grid search as a last resort**
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Close grid search as a last resort, except for categories of missing person that tend not to travel far.

Manage by objectives – use ICS, set objectives for an operational period, plan, and carry out the plan.

The missing person response

- Preplanning
- Notification
- Initial Response
- First operational period
- Subsequent operational periods ↻
- Suspension
  - Transition to Limited Continuing Search
- Critique

The alert student may note that this isn't quite the same as the IAMSAR Manual's scheme (Awareness, Initial Response, Planning, Operations, Conclusion).

Preplanning is added.

Initial response, followed by cycle of planning and operations.

Good phrase, rather than saying that the search is suspended, is to say that it is transitioning to a limited continuing search (i.e. primarily investigation, possibly with planned weekend searches by volunteer resources).

Critique is explicitly emphasized as important.

The missing person response

- Preplanning
- Notification ← Where to search?
- Initial Response ← Taming Chaos; ← Half of all searches are over in 3 hours and 10 minutes.
- First operational period
- Subsequent operational periods ↻ A few searches last five or more days.
- Suspension ← Accountability
- Critique

Highlighting some key bits along the way:

To put boots on the ground, you need to know where to put them.

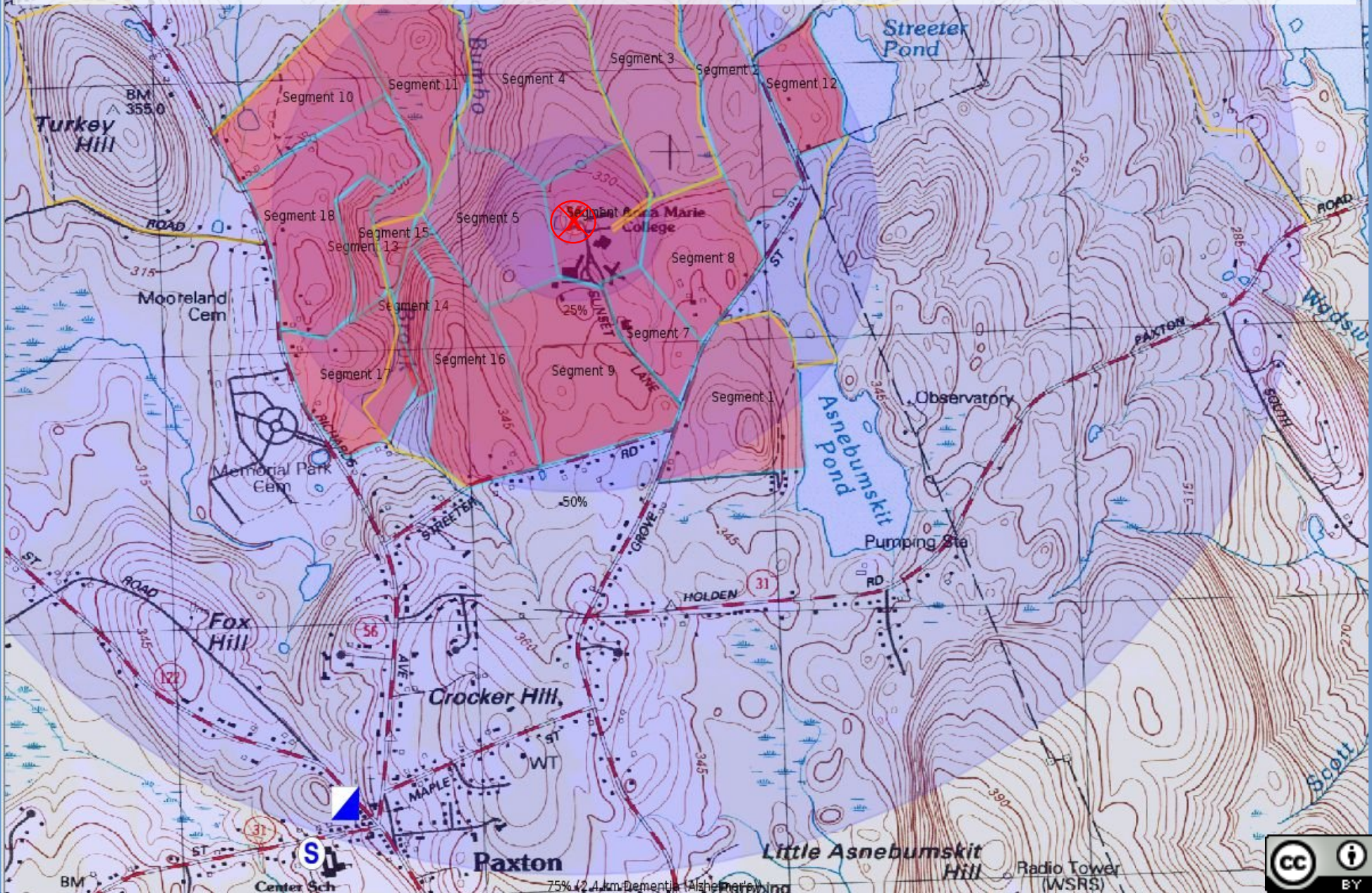
The initial response is all about taming chaos.

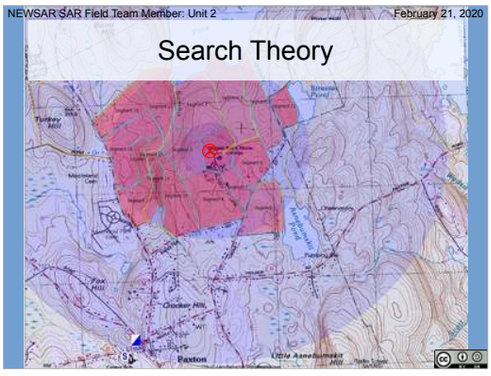
Half of all searches (by SAR resources) are complete in 3 hours and 10 minutes – initial response is very important.

Some searches last for days – and get very large – need to scale.

As people go home, key piece is making sure everyone gets home safe – accountability runs throughout a search.

Search Theory



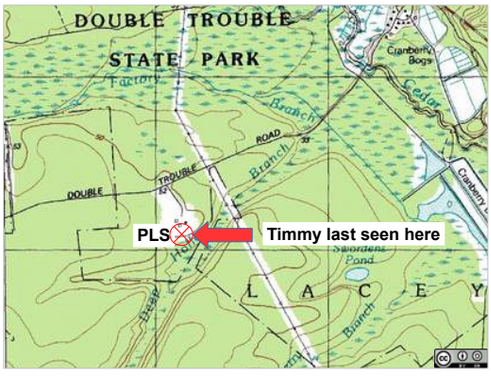


Unit 2: Overview of Search Theory.
Date Last Updated: February 21, 2020

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

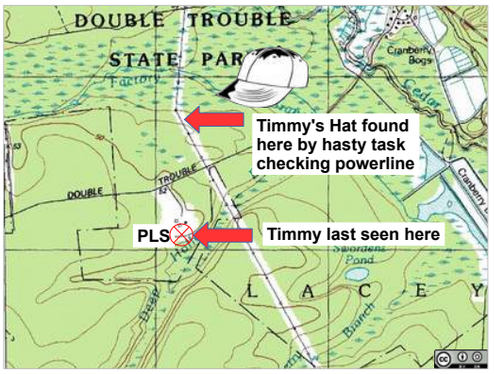
"The boys had been observed in the yard playing with a garden hose between 4:30 and 5:00 PM. Shortly thereafter, they were gone."

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

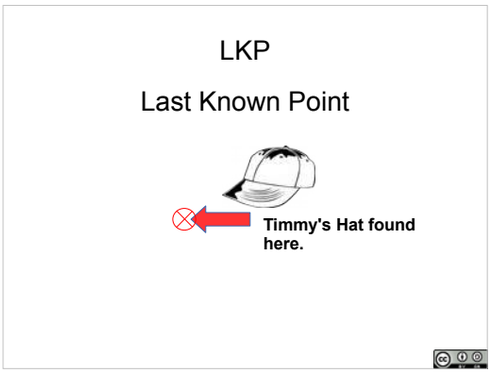
PLS: Point Last Seen

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).



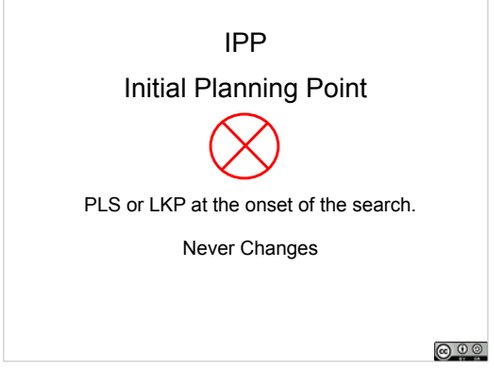
Searchers are called out, run a hasty task along the powerline and find a hat that is identified as Timmy's.



LKP: Last Known Point

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

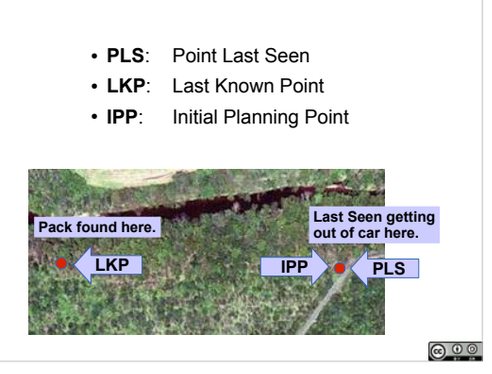
Can change over the course of a search (e.g. discovery of a trail register with an entry by the subject, or with the discovery of clothing or equipment abandoned by the subject).



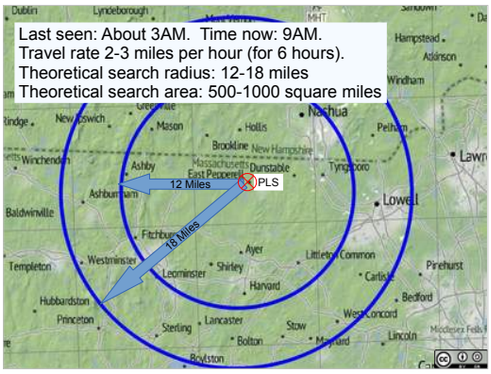
At the start of the search, the place where the subject was most recently known to be (whether it be a PLS or an LKP), is the Initial Planning Point.

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.



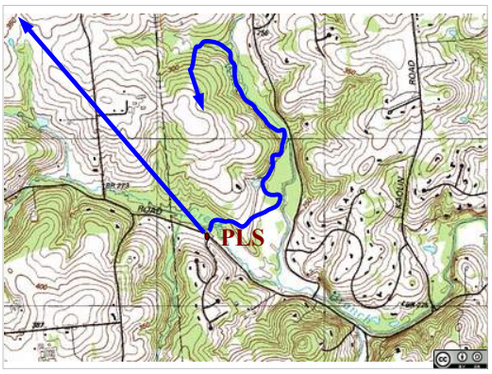
Reviewing, PLS,. LKP, IPP.



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.

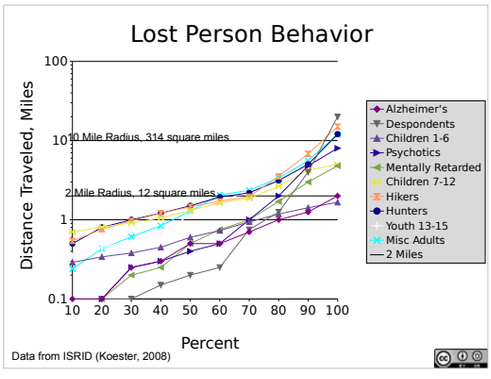
Theoretical search radius is just that – theoretical – the usual area within the theoretical search area is typically hundreds of square miles, much more than can be searched in a land search.



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.

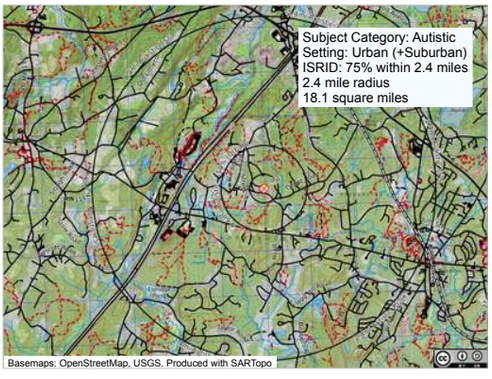
Terrain features can block, capture, and constrain the motion of lost persons in predictable ways.



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.

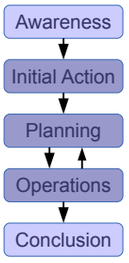
Theoretical search area is seldom practical or helpful.

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.

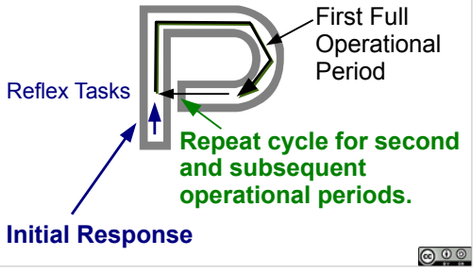
IAMSAR Manual: SAR Stages



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 ICS Planning **P**



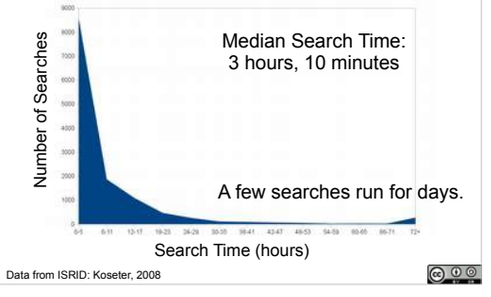
The Incident Command System has a concept very similar to the Initial Action + Planning and Operations Cycles: The planning P.

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



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**

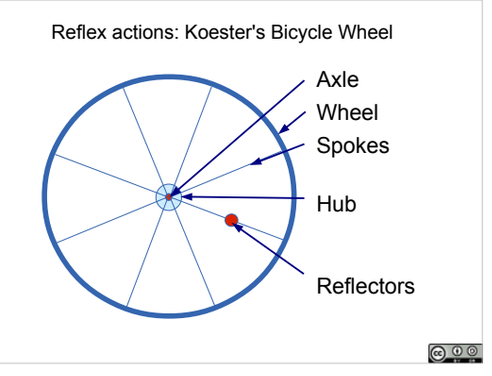
Initial Actions

- 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

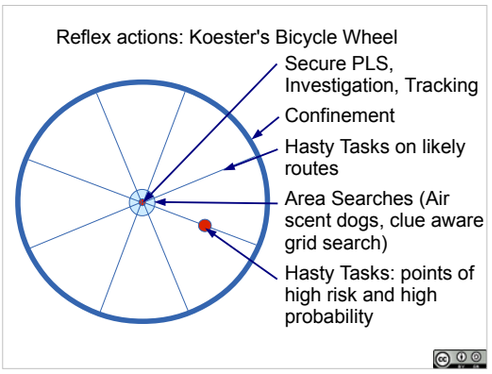
  Protect Clues
  - Secure the PLS
  - Scent Articles
  - Tracks

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.



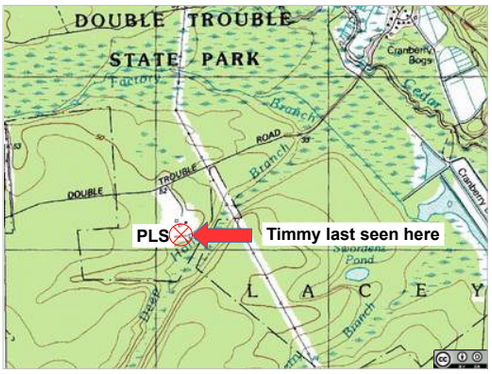
Axle: PLS – Secure it, investigation, resources that can provide a direction of travel.

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.

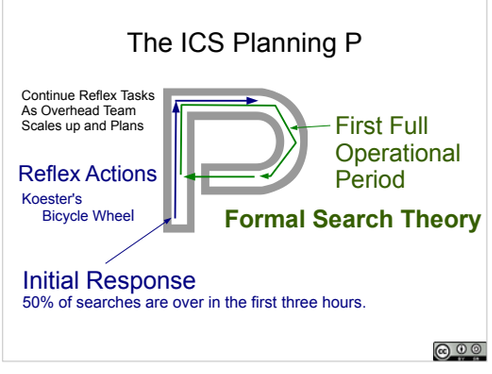


So, let's come back to the scenario: Timmy was last seen at a picnic area in Double Trouble State Park.

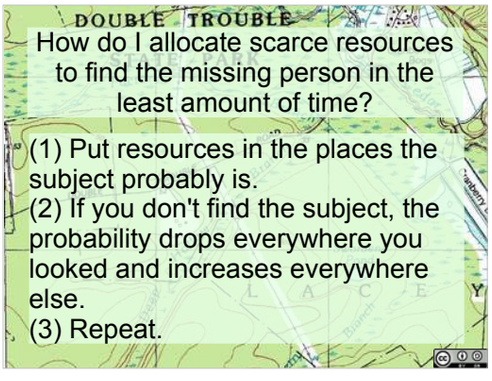
With Koester's Bicycle Wheel as a guide for Manage By Objectives, what objectives can we set for our initial/reflex actions?

Discuss.

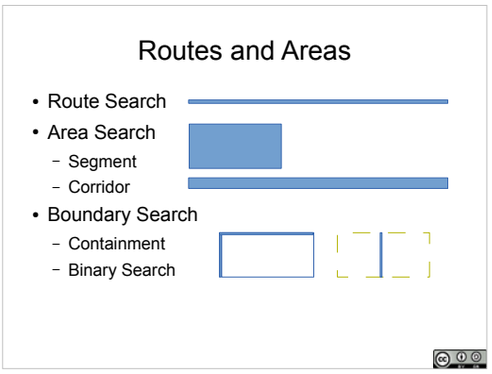
Tie proposals to axle, hub, spokes, wheel, and reflectors.



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.



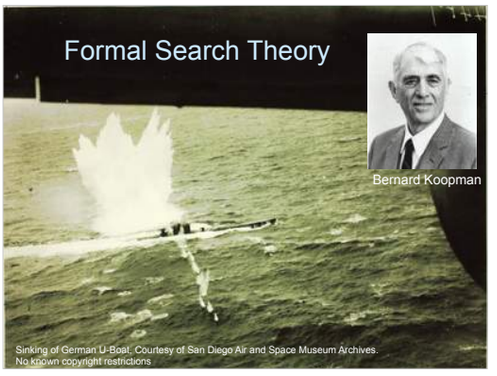
Formal search theory is all about resource allocation – where do we put limited resources to have the best chance of finding the missing person the soonest, and when you don't find them, shifting probabilities.



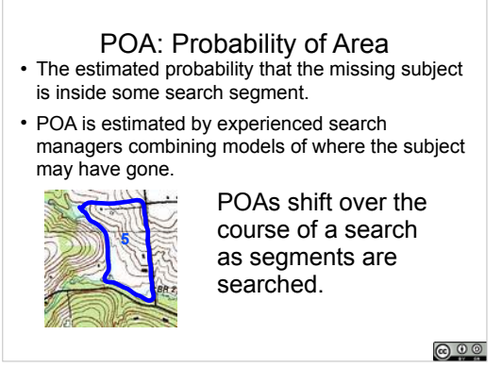
Oversimplified: Reflex tasking focuses on travel routes – which often have high probabilities, but there isn't a good statistical model of how to allocate resources to search travel routes. Formal search theory focuses on allocating resources to high probability search areas, then readjusting the probabilities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

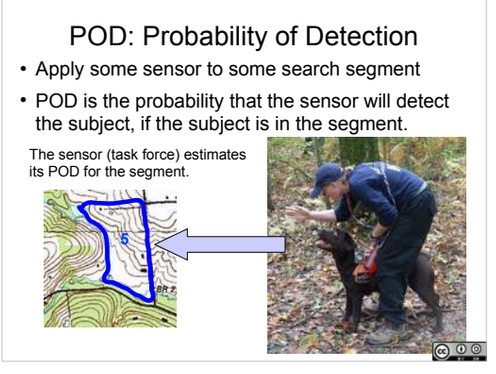


We start by assining a probability that the subject is in a search segment to each segment – Probability of Area.

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.



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.

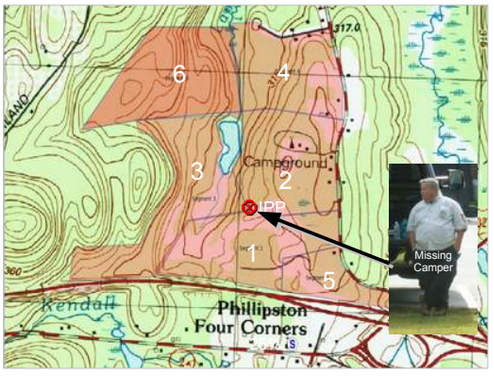
POS: Probability of Success

- 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)

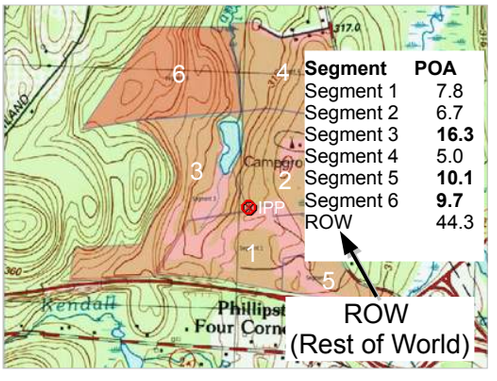
"For a given amount of available effort, there is an optimal effort allocation among the search segments that will produce the maximum OPOS [Overall Probability of Success]"

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



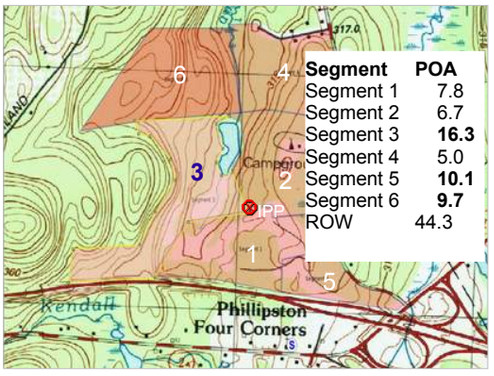
So, let's consider a hypothetical search for a missing camper.

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).



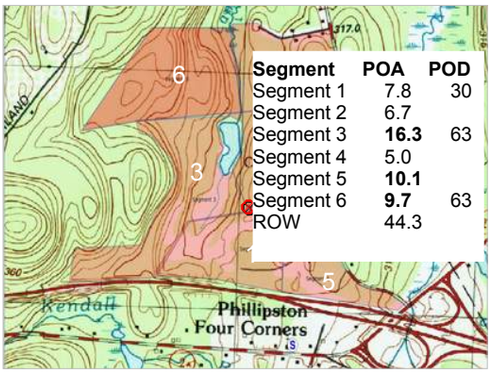
The search managers get together and estimate initial probabilities for each segment, leaving, here 44% of the probability outside the segmented area in ROW – rest of world.

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



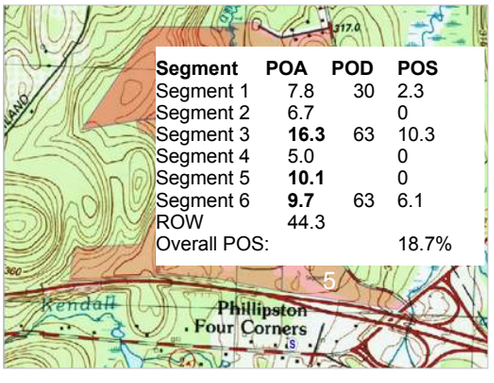
Segment	POA
Segment 1	7.8
Segment 2	6.7
Segment 3	**16.3**
Segment 4	5.0
Segment 5	**10.1**
Segment 6	**9.7**
ROW	44.3

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	

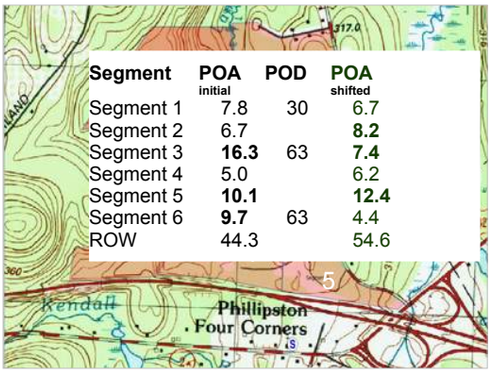
We put resources out to search segments 3, 6, and 1. They return and report probabilities of detection (of 30%, 63%, and 63%).



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%

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%.

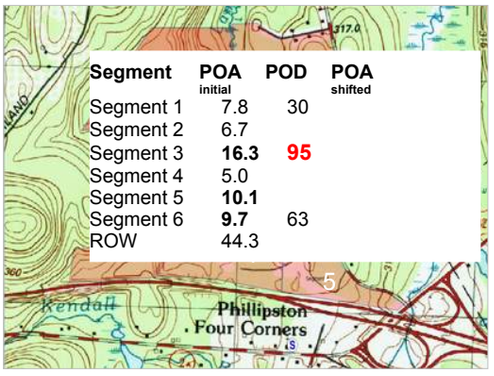


Segment	POA initial	POD	POA shifted
Segment 1	7.8	30	6.7
Segment 2	6.7		**8.2**
Segment 3	**16.3**	63	**7.4**
Segment 4	5.0		6.2
Segment 5	**10.1**		**12.4**
Segment 6	**9.7**	63	4.4
ROW	44.3		54.6

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.

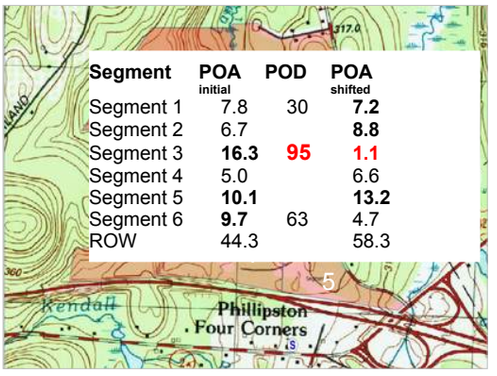
Where searchers reported a POD, the probabilities of area drop – and POAs rise everywhere else (including in ROW).

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



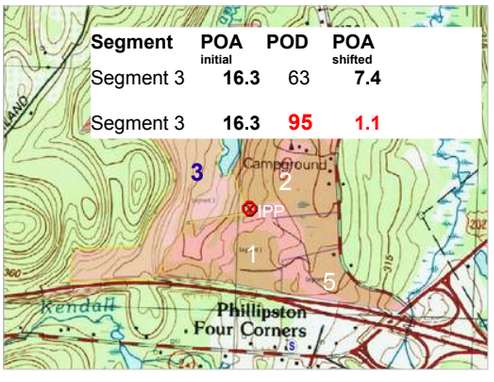
Now, let's suppose that the resource which searched segment 3 reported a 95% POD instead of a 63% POD.

What is the consequence?



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).

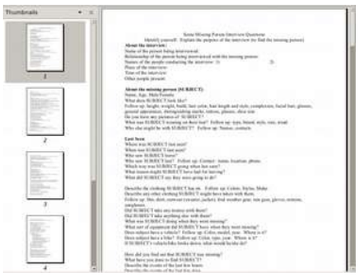
Here are some direct and indirect tactics.

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.

Lost Person Behavior

Unit 3: Introduction to Lost Person Behavior
Date Last Updated February 20, 2020 [crosschecked]

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Lost? Missing?

- Hiker underestimates time on trail, doesn't get home for dinner as planned, spouse calls 911.
- 82 year old with dementia wanders away from home.
- Hiker follows a game trail off trail into the woods.
- 4 year old wanders out of their home range
- Despondent parks their car and walks to a rocky overlook.

(Reviewing from Unit 1)
For each person:

Are they lost?
Missing?
Is it an emergency?

Lost

- You feel like:
  - You don't know where you are
  - You don't know how to get to where you want to be

What is lost?

Your point of view.

Missing – someone else doesn't know where you are.

Who's been lost?

What does it feel like?

Discuss. (take up to about 10 minutes)

This was a picture taken while lost. Caption reads: "After walking a while we hit a dead end. We decided, instead of turning back along the path, to trudge through the undergrowth as we thought it was close to linking in to the path at the other side. It certainly wasn't close to the other path and we ended up having to trudge through masses of undergrowth and a very dense forest before eventually getting lost at the edge of the wood. "
-- Neil Willamson

Response to being Lost

- Error at a decision point
- Fuzzy feeling that something isn't quite right
  - Denial
  - Early recognition of problem, more likely to backtrack.
- Panic Reaction
  - High Stress level
  - Reduced Performance at complex tasks (navigation)
- Anger to Bargaining to Acceptance
- Survival Strategy or Self Rescue Strategy

You act like you are lost if you feel lost.

Behaviors (Ken Hill)

- random traveling
- direction traveling
- route sampling
- direction sampling
- view enhancement
- backtracking
- using folk wisdom
- staying put

Lost people try things to get unlost.

Ineffective Strategies

- Discard Gear (75% injured or dead [n=4])
- Do Nothing (44% injured or dead)
- View Enhancing (33% injured or dead)
- Travel Cross Country (33% injured or dead)
- Wander (33% injured or dead)

Data from New Zealand Study

Some things don't work well.

New Zealand data.

View (and cellphone signal) enhancing is a strategy some experienced hunters and hikers use. In New Zealand it isn't a good strategy.

Strategies

- Seek Shelter (8% injured or dead)
- Route or Direction Sampling (11% injured)
- Travel towards landmark (15% injured or dead)
- Backtracking (16% injured or dead)
- Staying Put (24% injured or dead)
- Following a travel aid (25% injured or dead)
- View or Cellphone signal enhancing

Data from New Zealand Study

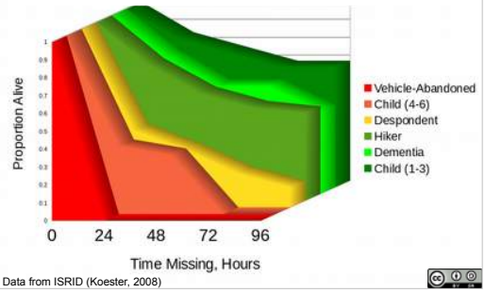
Some strategies are more effective – seeking shelter and direction sampling both seen as more effective.

Behaviors in Yosemite (74 cases)

- **Route Traveling** 41.9%
- Staying Put 25.7%
- Backtracking 16.2%
- Random Traveling 5.4%
- View Enhancing 4.1%
- Route Sampling 2.7%
- Direction Traveling 2.7%
- Doing Nothing 1.4%

Route traveling common amongst lost persons in Yosemite.

Survivability



Data from ISRID (Koester, 2008)

Survivability varies substantially with subject category.

Vehicle, abandoned very high risk.

Child 4-6 very high risk.
Child 1-3 much lower risk.

Factors Affecting Survivability

- Time
  - Most significant relationship
- Clothing, Equipment, Mental State, Fittness
  - Some relationship
- Experience, Survival Training
  - Minimal or no relationship

Time has greatest effect on survivability.

Experience and survival training have minimal to no relationship to survivability.

Lost Person Behavior Research

- 1973, Dennis Kelley: 308 cases, Colorado
- 1977, William Syrotuck: 229 cases, NY, WA
  - First subject categories
- 1985, Barry Mitchel: 3511 cases, CA, CO, East US
  - Regional differences
- 1986, Ken Hill – Behaviors when lost
- 1992, Robert Koester – Alzhemier's, VA
- 1997, Heth & Cornel – Dispersion
- 2011, Perkins, Roberts & Feeney: 1271 cases, UK
- 2012, Robert Koester: 16,863 cases ISRID

Long history of research on the behavior of lost persons.

ISRID: International Search & Rescue Incident Database

- Global Data Set
- Compiled by Robert Koester
- Initial 2002 funding from USDA
- 2008 (Lost Person Behavior book): 31,100 cases
- 42 Behavior Categories
- 2014 > 60,000 cases
- 2017 > 145,000 cases

Key tool in studying lost person behavior is ISRID.

Summarize some of Robert Koester's findings from there.

Statistically observed behaviors All differ among categories

- Distance from IPP to Find
- Travel Uphill or Downhill
- Time mobile (generally hours)
- Where found (structures, brush, woods, etc)
- Distance found from Roads/Tracks

Identifying a behavioral category for a lost person is important – people in different behavioral categories have statistically different behaviors.

Behaviors and Search Tactics

- Active or passive tactics?
- Call the Subject's Name?
- Where to search
  - Where to put field searchers?
  - Where do the field searchers look in their segment/route?
  - Investigative directions to elicit planning data.
- Decision points (map and field)

Subject behavioral category can suggest approaches to search – at both the larger planning scale and in the tactics to employ by searchers in the field.

Related idea is decision points – identifying places where the subject may have gone wrong and analyzing where they might have gone after an error at a decision point.

Some Categories

- Child 1-3
- Child 10-12
- Autism Spectrum Disorder
- Dementia/Alzheimer's
- Despondent
- Hiker
- Hunter
- Abduction

Categories have refined over time, here are some common ones distinguished in ISRID.

We'll walk through these categories.

Child (1-3)

- Tend to be very close to the IPP
- Tend to shelter/hide in structures, brush, inside logs – look anywhere they can fit.
- Check anywhere they may fit within abandoned vehicles.
- Often drawn to animals or water.
- Can sleep through loud noises.

Very young children don't tend to travel far.

They tend to shelter/hide/curl up and sleep somewhere small.

Look anywhere they may fit.

Will shelter and hide anywhere they can fit. Will shelter in a hollow log in the back yard.

Can go to sleep and sleep through searchers walking right past them calling their name.

Check any place a missing child may fit.

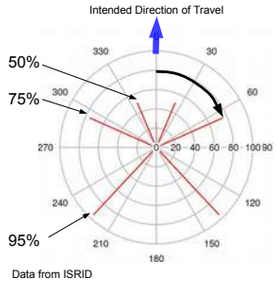
Check Structures

Abandonded vehicles, structures, old appliances, etc.

Anywhere they may fit.

Many categories of lost person are found in structures.

Dispersion Angle: Child (1-6)



75% are within 66 degrees of the intended direction of travel

Data from ISRID

Top of circle is intended/last known direction of travel from IPP. Red lines indicate proportion of subjects found within that angle from the direction of travel.

50% within about 30 degrees.
75% within 66 degrees
95% within about 140 degrees – a small portion found off in the opposite direction.

Check Structures (Temperate)

- Mental Retardation: 34%
- Child (1-3): 29%
- Child (4-6): 29%
- Child (7-9): 29%
- Child (10-12): 29%
- Abduction: 29%
- Despondent: 26%
- Child (13-15): 25%
- Worker: 25%

Structures are a pattern for many subject categories, including all children.

Check Structures (Urban)

- Child (13-15): 80%
- Mental Retardation 57%
- Child (4-6): 56%
- Child (7-9): 56%
- Child (10-12): 56%
- Child (1-3): 50%
- Despondent: 47%
- Dementia: 35%
- Hiker: 24%

Even more pronounced in urban/suburban areas.

Less often found in structures

- Dementia: 20%
- Mountain Biker: 14%
- Snowmobiler: 14%
- Hiker: 13%
- Hunter: 8%
- Runner: No cases (small sample size)
- Skier – Nordic: No cases (small sample size)

A few subject categories are less likely to be found in structures.

Let's look at children 10-12.

Child (10-12)

- Often adventuring, exploring, fantasy play,
- Often take shortcuts.
- Often make mistakes at decision points.
- May be well outside home range.
- Signcut and evaluate field decision points.
- Check anywhere they may fit within abandoned vehicles.

Very mobile and explore.

Can be well outside their usual home range. Home range as reported by the parents is usually an underestimate.

Look for decision points.

Check structures, check abandoned vehicles.

Substance Abuse

Substance Abuse

- Often investigative finds (29%)
- Very high mortality rate (42% Urban)
- Typically poorly dressed for the weather
- Point last seen often a bar or party, subject leaving on foot
- **Often drawn to water**

About a third not lost but found through investigation. Tend to be poorly dressed. High mortality rate. Typical pattern: seen at a bar or party, left on foot.

Often drawn to water.

Autism Spectrum Disorder

- **Attracted to lights, water, reflections**
- May be attracted to animals, transportation.
- May have catastrophic reaction if overstimulated.
- Often in structures.
- Very unlikely to respond to searchers.

Autism Spectrum Disorder.

General pattern of attraction to lights, water, reflections. Check nearby water.

May have specific attractor, often transportation related or animal related.

Unlikely to respond to searchers calling their name.

Upon a find, minimize noises (radio volume), number of people, and work to provide a calm, quiet environment.

Dementia

- Stop moving within hours
- Very unlikely to respond to searchers calling their name
- Tend to leave few clues other than sign
- Often in drainages, creeks, or brush
- May be stuck in dense brush.
  - **Keep going until they get stuck**
- Tend to leave or cross roads
- May have catastrophic reaction

Characteristic of critical elderly wanderers:

They keep going until they get stuck.

Like Autism Spectrum Disorder, upon a find, minimize noises (radio volume), number of people, and work to provide a calm, quiet environment.

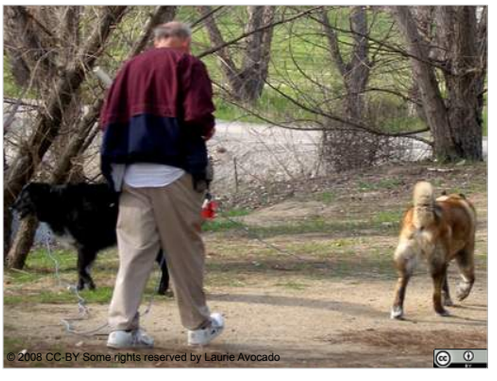
Dementia

- IPP is residence or nursing home
- Oriented to the past
  - May attempt to travel to former place of work
  - May attempt to travel to former home
- May have wandered before
- May use public transportation
- **Look for decision points where the route turns but the subject could have kept going straight.**

Tend to be oriented to the past and may be thinking they are going to work or going home or going to church, or some activity that they used to do frequently.

They may use public transportation, even if they don't have money for a fare (some nice person may have paid the fare for the little old lady or gentleman...).

Tend to cross and leave roads – more generally, tend to travel straight unless they encounter a barrier.



Characteristic picture.

Unsteady on their feet, so they tend to look down.

Dementia tends to affect short term memory – thus affects the ability to use landmarks for navigation (look up, see the landmark, look back down and forget it).

Effects of Dementia on Navigation

- Short term memory problems → Can't see or recall Landmarks
- Reduction in Peripheral Vision
- Difficulty judging passage of time → Can't estimate Distances
- Reduced visual-spatial skills → Poor sense of Direction

LOST

Dementia tends to affect sense of time – what's the main thing we use to estimate distance traveled? Time traveled.

Dementia tends to degrade the ability to navigate – less able to use landmarks, less able to estimate distances traveled, reduced sense of direction.

All lead to more easily becoming lost.

Exercise to help understand navigation in critical elderly wanderers – look down (unsteady on feet), hold your hands on either side of your eyes (reduced peripheral vision), walk, keeping looking down (unable to remember landmarks).

Here are students in a lost person behavior class doing this exercise at a location that was the IPP for a missing couple with dementia. The gravel road turns right up ahead at a junction to a trail leading into the woods. Everyone in the class went straight onto the trail (as the lost couple did).

Look for, examine for sign, and report, field decision points where a subject with dementia could have gone straight and missed a turn in a travel route.

They go until they get stuck

Hallmark pattern. Travel in a straight line until they can't go any further.

How Far?

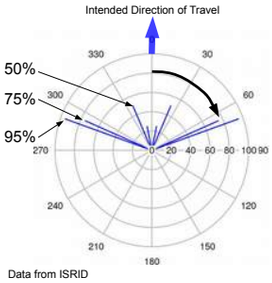
North East, less that 1000 feet relief: Temperate Flat

175 cases (global – dementia, temperate flat)

25% within 0.2 miles
50% within 0.6 miles
75% within 1.5 miles
95% within 7.9 miles

Critical elderly wanderers will travel much farther than caregivers think they can.

Direction of travel is strong predictor



Dementia: 75% are found within 66 degrees of the intended direction of travel

Data from ISRID

75% within 66 degrees of intended direction of travel.

The door they exited from is a very strong predictor of where they will be found.

Despondents

Find Location

- Temperate
  - Structure (26%)
  - Woods (25%)
  - Water (15%)
- Urban
  - Structure (47%)
  - Water (19%)

Most likely:
On a trail, path, or at their destination.
Survivors often in structures.
Often at interface between terrains.
Rarely in Brush
Seldom respond to searchers.

Often just out of sight at an interface between different sorts of land cover (just inside the tree line at the edge of an open area, on the shoreline of a lake).

Tend to be missing, not lost.

Check structures.

Two Patterns

- Get Just out of Sight
  - Urban 50% within 100 meters of IPP
  - Often at urban/rural interface or at treeline
- Travel to Scenic or Significant (to them) Location
  - Viewpoints
  - Just out of sight at that destination

Temperate less that 1000 feet relief: 50% within 0.7 miles of IPP
Temperate more than 1000 feet relief: 50% within 0.5 miles of IPP
Urban, 50% within 0.5 miles of IPP

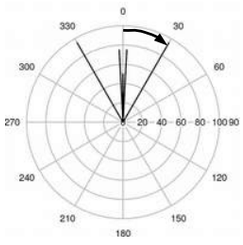
Two typical patterns:

Just out of sight at the IPP.

or

Traveled to a significant place and just out of sight there.

Dispersion Angle: Despondent



95% within 30 degrees of intended direction of travel

Data from ISRID

Direction of travel is very strong predictor of find location, 95% within 30 degrees.

Hunter

Hunters (rifle,shotgun,primitive,bow)

Hunting tactics (and resulting navigation behaviors) will vary.

Hunter

- Mostly (70%) Lost
  - May be focused on game, not navigation.
- Often travel at night (40 to 80%)
- Likely to follow a self rescue strategy
- May be comfortable sheltering overnight
  - Particularly older and more experienced hunters
- Follow both linear features and terrain.
- Type of hunter (Bow/Shotgun/Rifle) and game (Deer, Wildfowl, Bear, etc) very important.

Pursuit of game and nightfall most common causes of becoming lost.

In following game, may get into very dense brush, boulder fields, dense forest, etc.

Go to great lengths to self rescue.

Dispersion Angle (Hunter, Nordic Skier, Snowmobile, Hiker-dry)

Hunter: 75% within 175 degrees of intended direction of travel

Intended direction of travel is poor predictor of find location.

Data from ISRID

May be anywhere – intended direction of travel is poor predictor of find location.

Some other classes of lost person have similar lack of predictability of direction of travel (cross country skiers, snowmobilers, hikers)

Hikers

Follow trails.

As ground searchers, you are expected to have a higher level of skill and be able to navigate effectively off trail. Hikers may well not have off trail navigation skills.

Hiker

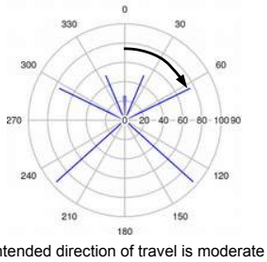
- Tend to be on or close to trails or linear features
  - Off trail, often follow terrain onto linear features
- Mostly (68%) Lost
  - Errors at decision points
  - Errors where trails are obscure (field decision points)
  - Leaving trail for game trail
  - Leaving trail for herd path
  - Leaving trail to cut switchbacks
  - Taking wrong direction on trail
- Some (16%) Overdue, errors in estimating time or physical fittness
- Often (30 to 40%) travel at night

Get into trouble when they get off the trail.

Decision points are very important for missing hikers – pay particular attention to field decision points (check for sign, report).

Can be very easy to get off trail – above tree line, in places where trail system is poorly marked, etc.

Dispersion Angle: Hiker



Hiker:
75% within
64 degrees
of intended
direction
of travel
(Temperate)

Intended direction of travel is moderate predictor of find location.

Data from ISRID

Intended direction of travel is poor predictor of find location.

Abduction

- Red Flags
  - White Female, age 5-12
  - Missing from a familiar location
  - Hasn't done this before (no history of running away)
  - No explanation for disappearance
- Rapid Law Enforcement Response is Critical
- Only 16% are found alive

Abduction – stranger abductions.

Multiple Crime Scenes

- PLS
- Initial contact site
- Assault site
- Murder site
- Dump site
  - Body likely to be concealed
  - Likely to be in a different jurisdiction from the PLS. 50% are within 10 miles of PLS.

Abductions have four characteristic crime scenes – the location where the subject was initially contacted by the perpetrator, the site where the perpetrator committed the assault, the murder site, and the site where the perpetrator dumped the body. More than one event may have occurred at the same place.

Be alert for all of these and for clues at each in a known or potential abduction.

Typical pattern for dump sites in abductions.

Dump Site

- Turnoff – within 1/2 mile of a junction
- Near a main road
- Vehicle Access – within 300 feet of vehicle
- Near water or in the water
- Downhill (if there is a slope)
- Remote location: Out of sight

Search carefully for clues and sign at locations with the characteristics of typical dump sites.

Some Other Categories

- Climbers (day climbers, mountaineers)
  - Weather, hazards often involved.
- Gatherers
  - Typically looking for a very specific habitat
- Mental Illness
  - Often Evade Searchers – May attack Searchers
- Camper (Car Camper)
  - Poorly marked trails near campground
  - Often overdue

Plenty more categories.

Distances of Find from Linear Features (50% distance)

- **Autistic : 15 meters**
- **Dementia: 15 meters**
- **Mental Retardation: 15 meters**
- Despondent: 50 meters
- Hiker: 100 meters
- Hunter: 100 meters
- Worker: 2500 meters (small number of cases)

Track offset – some categories are often close to travel routes.

Some tend to be off trail.

Approaching the Subject

Particularly autistic and dementia:

- **May have catastrophic reaction**
- Simplify the environment
  - Reduce noise, turn down radios, etc.
- Approach from the front
- Make eye contact
- Ask simple direct questions.

When you make a find, be cautious approaching the subject.

Learning More:

- Robert Koester's Book: “Lost Person Behavior.”
- Robert Koester's Lost Person Behavior course.

Robert Koester has good resources on lost person behavior – applicable to both search management and field tactics.

Practical Evolution 1. Walking like a person with dementia.

The material in this unit draws heavily from the writings of Robert Koester. His research and teaching in the field of Lost Person Behavior is very gratefully acknowledged.