Visibility-based terrain analysis and reasoning for Combat Search And Rescue operations

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Improve Canada's defence capabilities through research and development:

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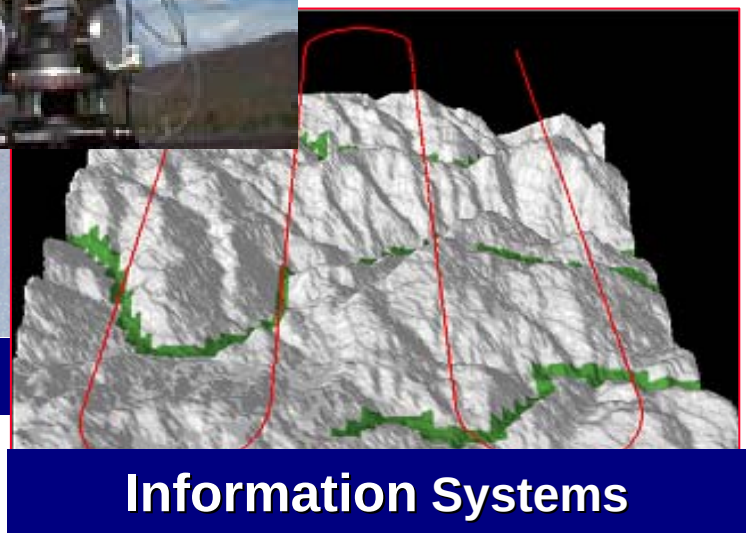
Sectors of Activity



Outline

- Presentation of the concept
- North Atlantis Scenario
- Assets and communication graph
- Interpreted systems for Situation Analysis
- Preprocessing and system generation
- Conclusion

Visibility-based terrain analysis and reasoning for CSAR ops

Presentation of the concept

Main steps in CSAR ops

(1) *Awareness and notification*, where the notification that personnel is missing or isolated from friendly forces is received,
(2) *situation assessment*, where all available information regarding the isolated personnel's location and status is analysed and measures are taken to enrich this information if necessary (searching, satellite coverage, etc.),
(3) *mission planning*, where the decision whether a CSAR operation is to take place is taken and, if so, the detailed planning for the operation is done,
(4) *execution*, where the CSAR operation is conducted in accordance with the plan laid in 3, and
(5) *mission conclusion*, where the rescued personnel, if necessary, is delivered to the appropriate medical treatment facility and post mission reports are made.

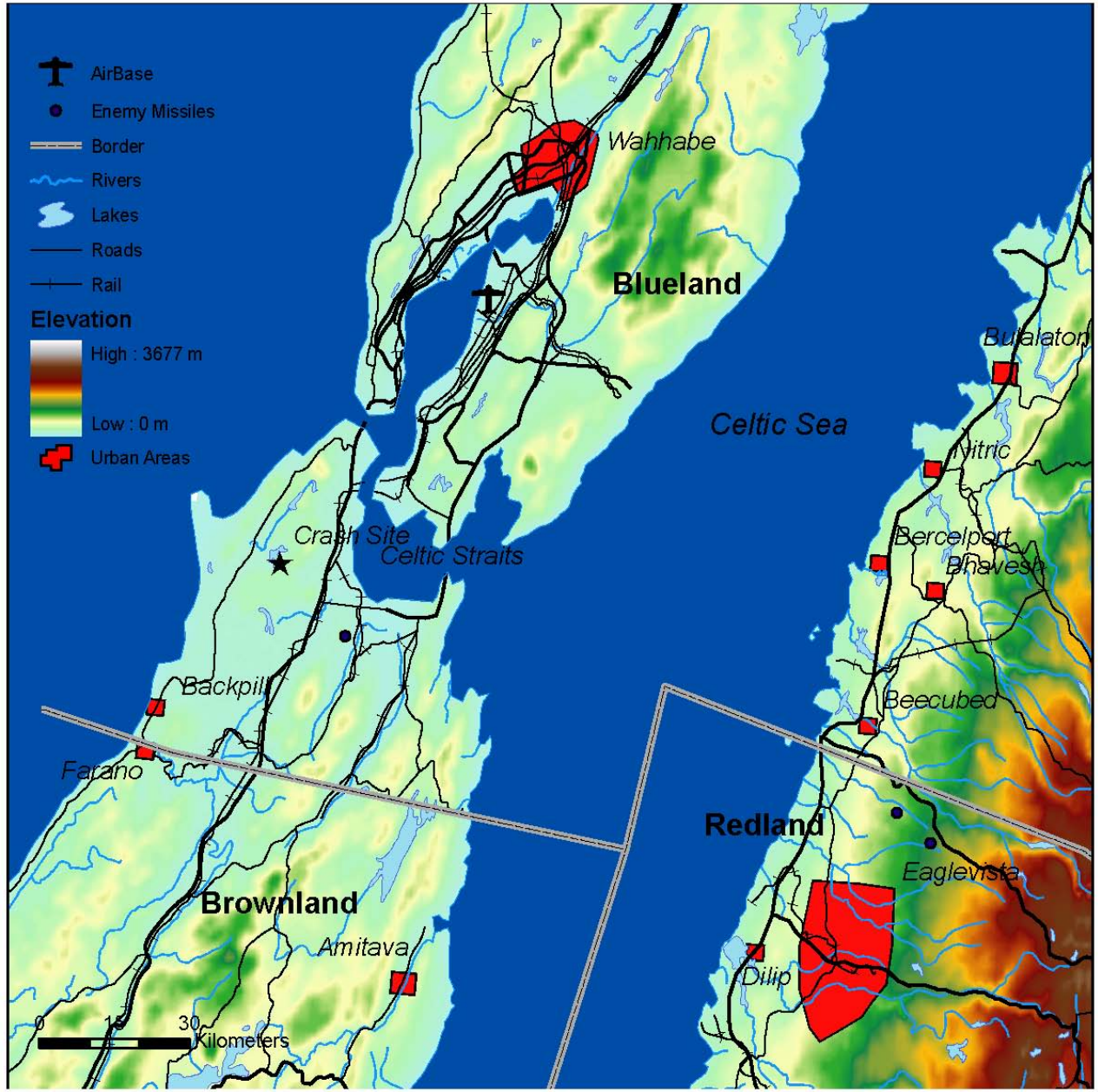
Approach

- Scenario-based design
- Visibility-based terrain analysis
- Characterisation of agent mobility
- Selection of efficient paths

North Atlantis Scenario

The GIS database and basic processing


Greenland
Iceland
Finland
Norway
Sweden
Faroe Is.
Denmark
Blueland
Orangeland
Germany
United Kingdom
Netherlands
Redland
Ireland
Belgium
Luxembourg
Jersey
Switzerland
France
Italy
Brownland
Whiteland
Andorra
Greyland
Spain
Portugal
Gibraltar
Algeria
Morocco
0 250 500
Kilometers


AirBase
Enemy Missiles
Border
Rivers
Lakes
Roads
Rail
Elevation
High : 3677 m
Low : 0 m
Urban Areas
Wahhabe
Blueland
Celtic Sea
Bulalaton
Nitric
Crash Site
Celtic Straits
Bercelport
Bhavesh
Backpill
Beecubed
Farano
Redland
Eagleviste
Brownland
Amitava
Dilip
0
15
30
Kilometers

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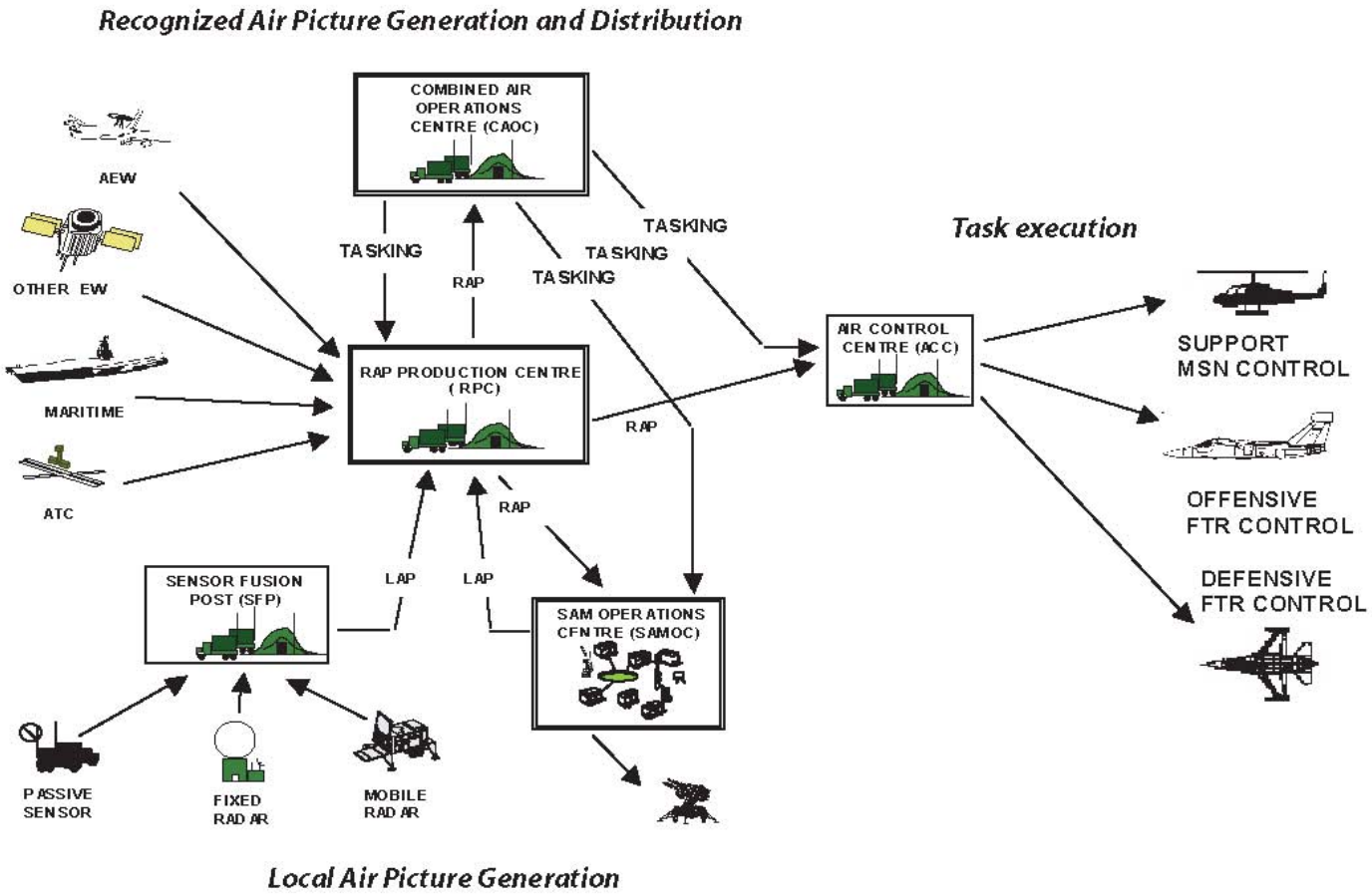
North Atlantis Scenario

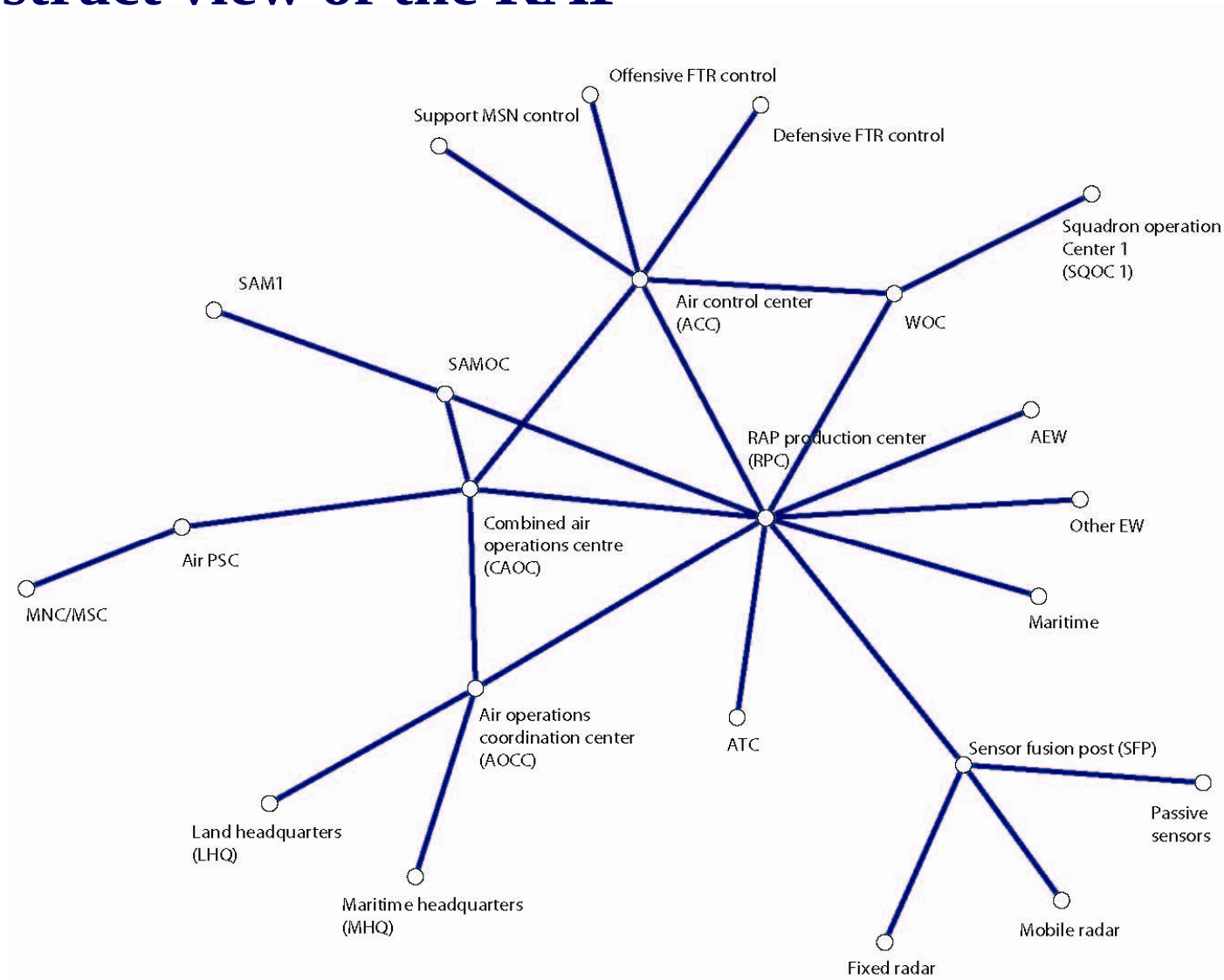
The CSAR components and communication network

Recognized Picture: from Generation to Task Execution



P. Maupin and J. Fitzback (2005), Adapted from *The NATO Air Command and Control System (1997)*

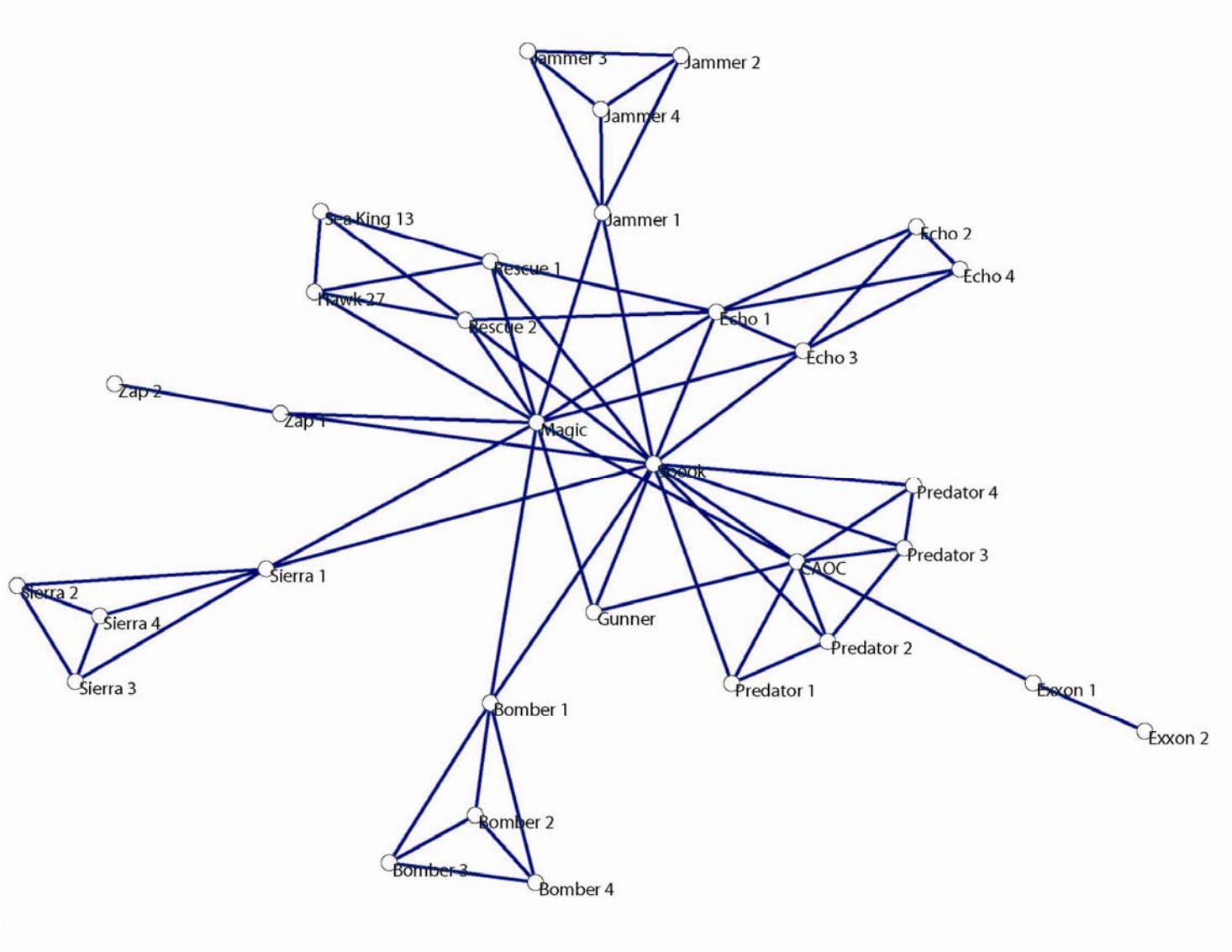
Abstract view of the RAP



Assets and roles

Depiction	Entity	Call Sign	Role
	U-2	U-2	ISR
	Predator	P-1/2/3	ISR
	ECR Tornado	Jammer 1-2-3-4 Zap 1-2	SEAD
	CF-18	Sierra 1-2-3-4	Fighter Sweep
	CF-18	Echo 1-2-3-4	Fighter Escort
	CF-18	Bomber 1-2 3-4	Fighter Bomber (BAI)
	AC-130	Gunner	Close Air Support
	MiG 31	M-1/2/3/4	Enemy Fighter
	CH-53	Rescue 1-2	CSAR Helicopter
	MI-24 Hind	H-1/2	Enemy Attack Helicopter

Abstract view of the CSAR Vignette

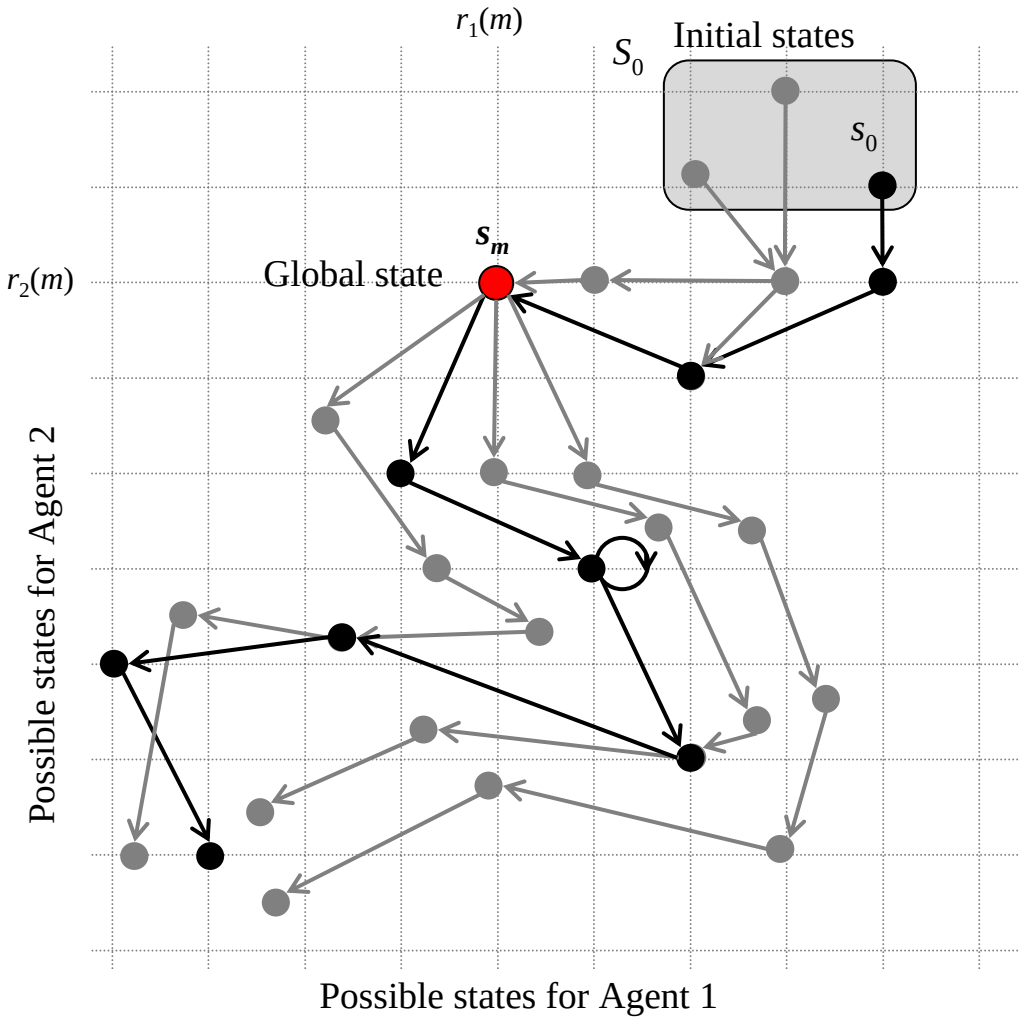


Interpreted Systems for Situation Analysis

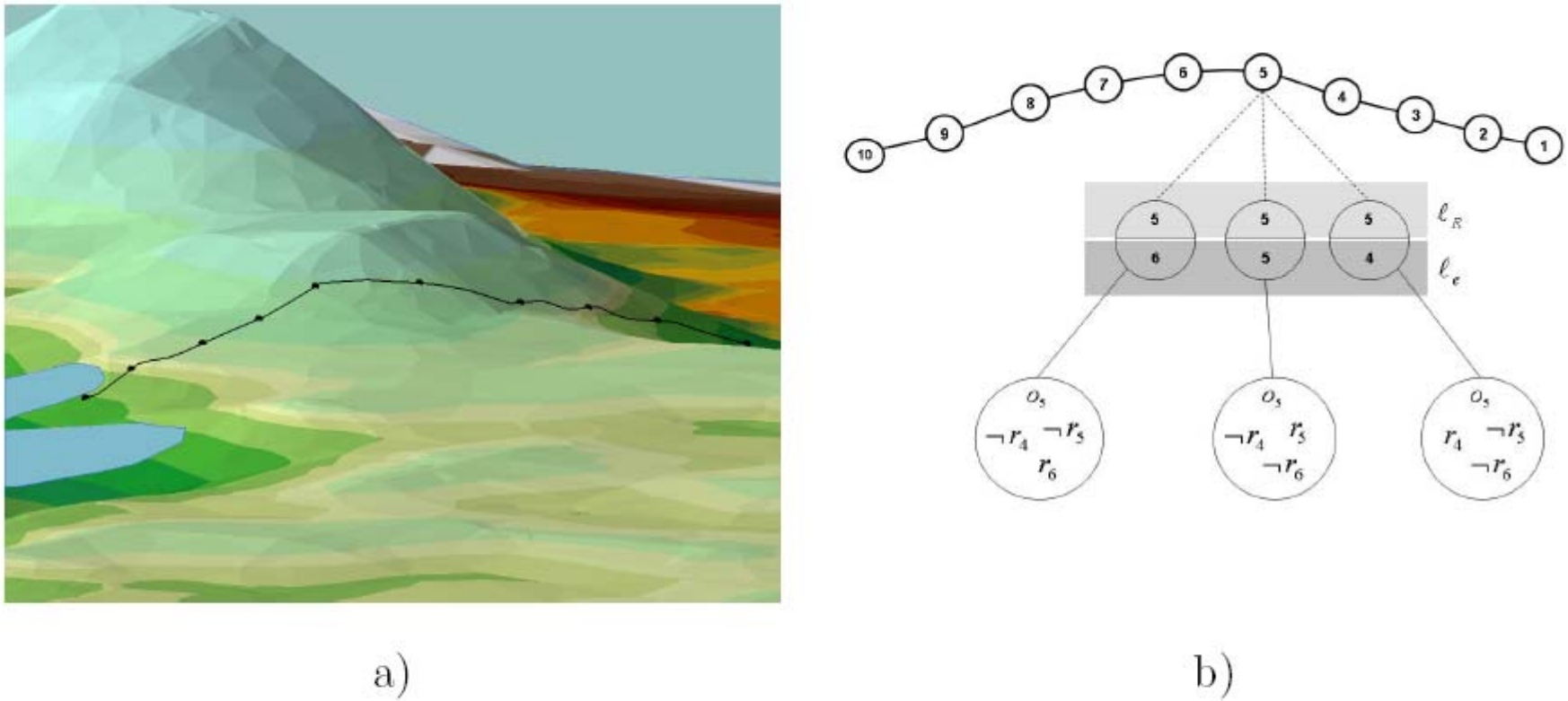
Maupin, P. Jousselme, A.-L., “A general algebraic framework for situation analysis," in Proceedings of the 8th *International Conference on Information Fusion*, (Philadelphia, PA, USA), July 2005

Interpreted systems

A system is the set of possible runs.



Interpreted systems

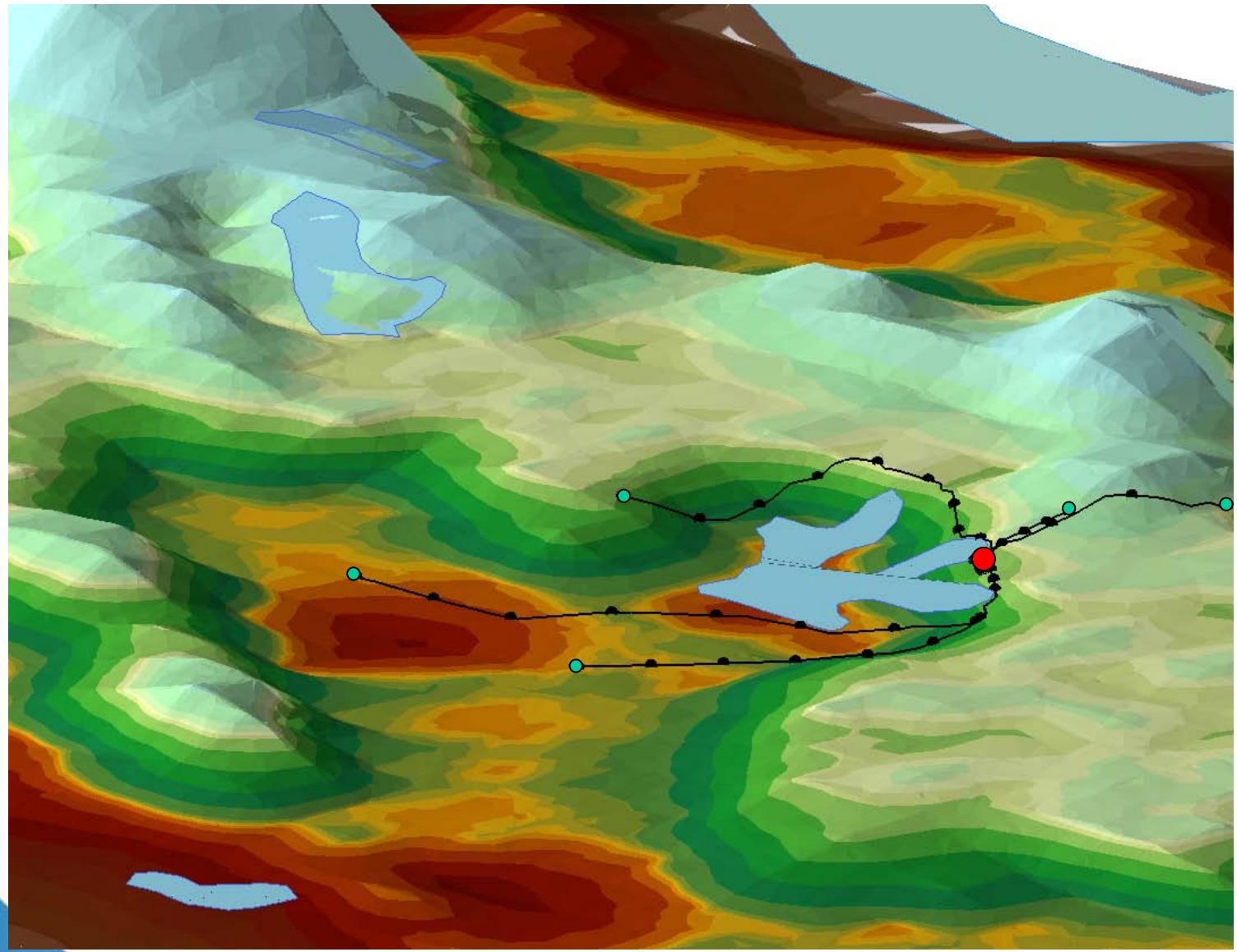


a) b)

Fig. 8. The path of example 2. In figure a), the path is shown in the terrain. In figure b) the worlds thought possible by the rescuer when it observes that he is in position 5 are included, and for each possible world, some propositions true in these worlds are shown.

Preprocessing and system generation

Least cost paths from landing sites



Suitability of landing zones

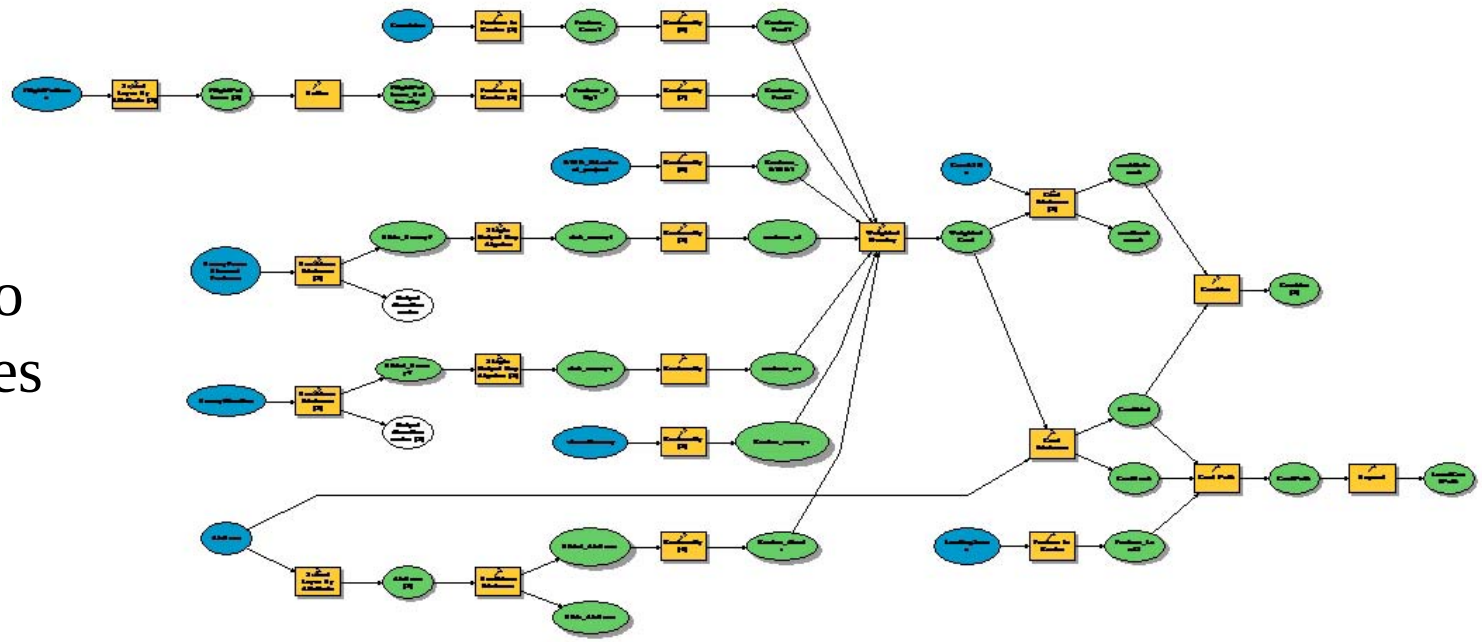
	Included	*Excluded*
Slope	<= 6 degrees	> 6 degrees
Vegetation	Grassland, pasture.	Mountains, deciduous, coniferous, wetlands.
Distance	A relative ranking was given, based on the straight line distance from the airbase.	
Hydrology	N/A	Rivers, lakes.
Man made obstacles	N/A	A buffer distance around the obstacle based on the obstacle's height.
Visibility	Not visible by hostile forces.	Hostile force visibility of landing zone.
Size	>= 100m	< 100m
Territories	Friendly.	Hostile, unknown.

Least cost path analysis

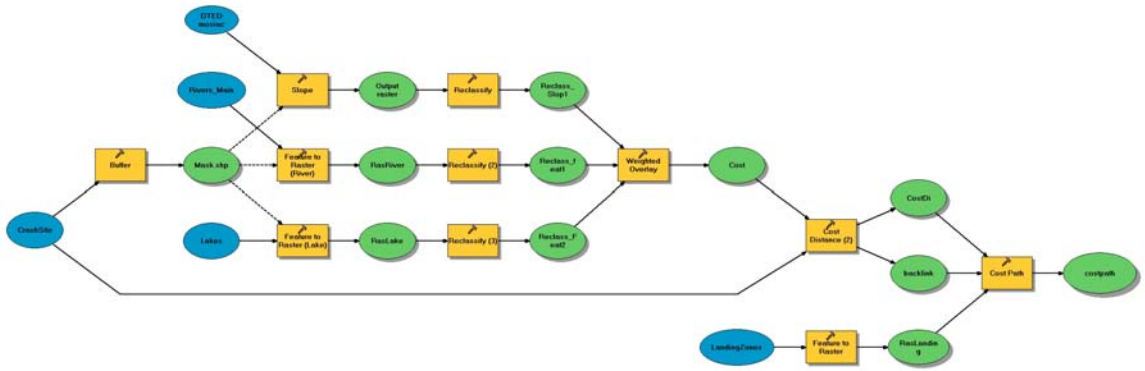
	Ranking	Value	Weight
Elevation	1	<=300m	5
	9	> 300m	
Territories	1	Friendly	5
	5	Unknown	
	9	Hostile	
Distance from Hostile Locations	Relative ranking based on exponential distance from hostile locations.		10
Enemy Visibility	1	Cannot be seen or are not within weapons range of the enemy.	50
	9	Can be seen or are within weapons range of the enemy.	
Distance from Airbase	Relative ranking based on the straight line distance from the airbase.		5
Existing Flight Patterns	1	No existing flight patterns within a distance of 5km.	25
	9	Existing flight patterns or areas within a distance of 5km of an existing flight pattern.	

Least cost path model

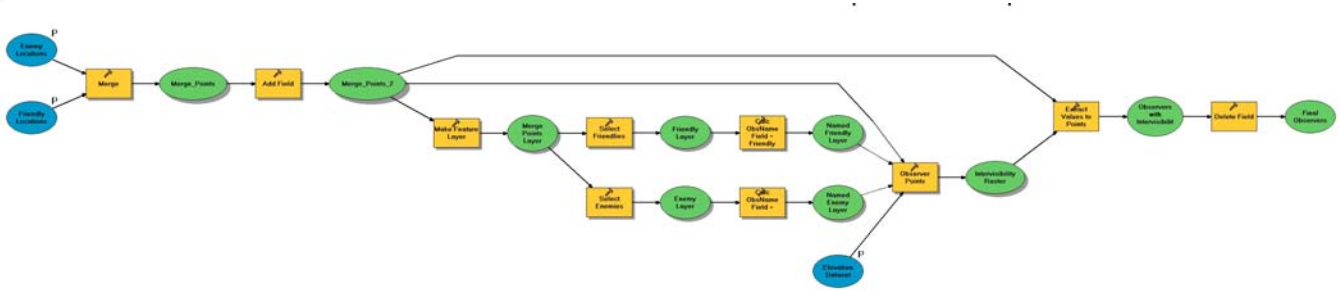
From base to landing zones

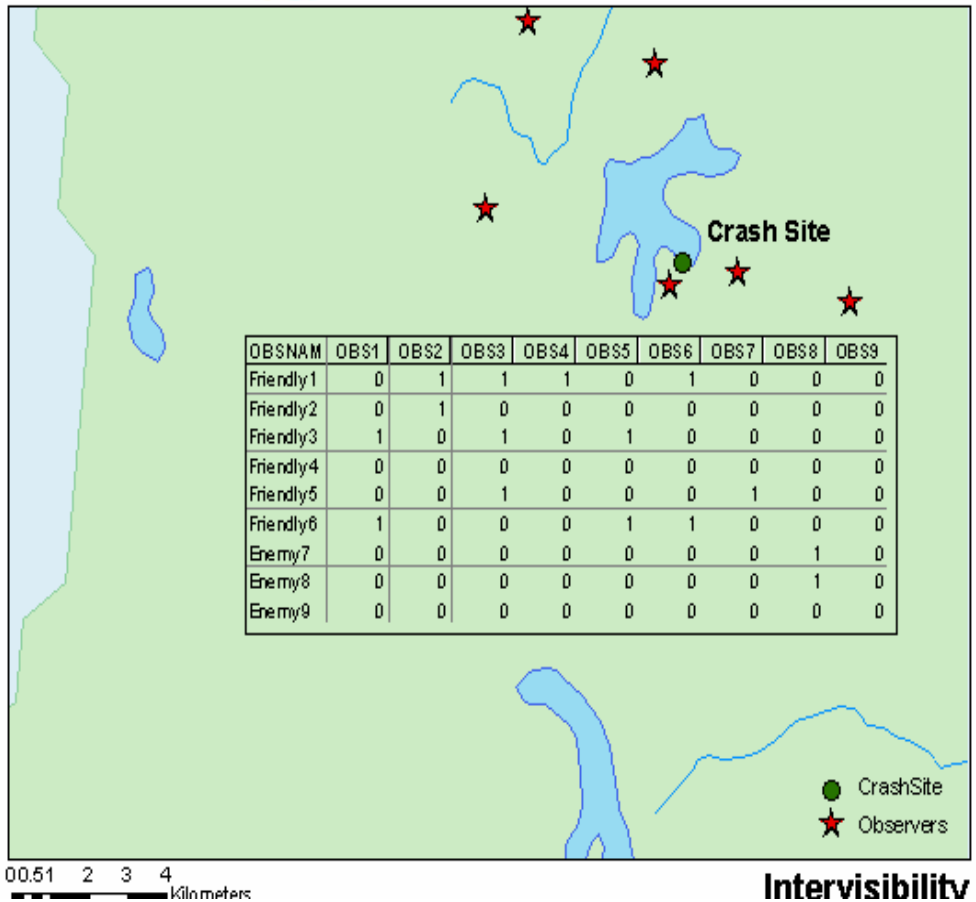


From landing zones to crash site



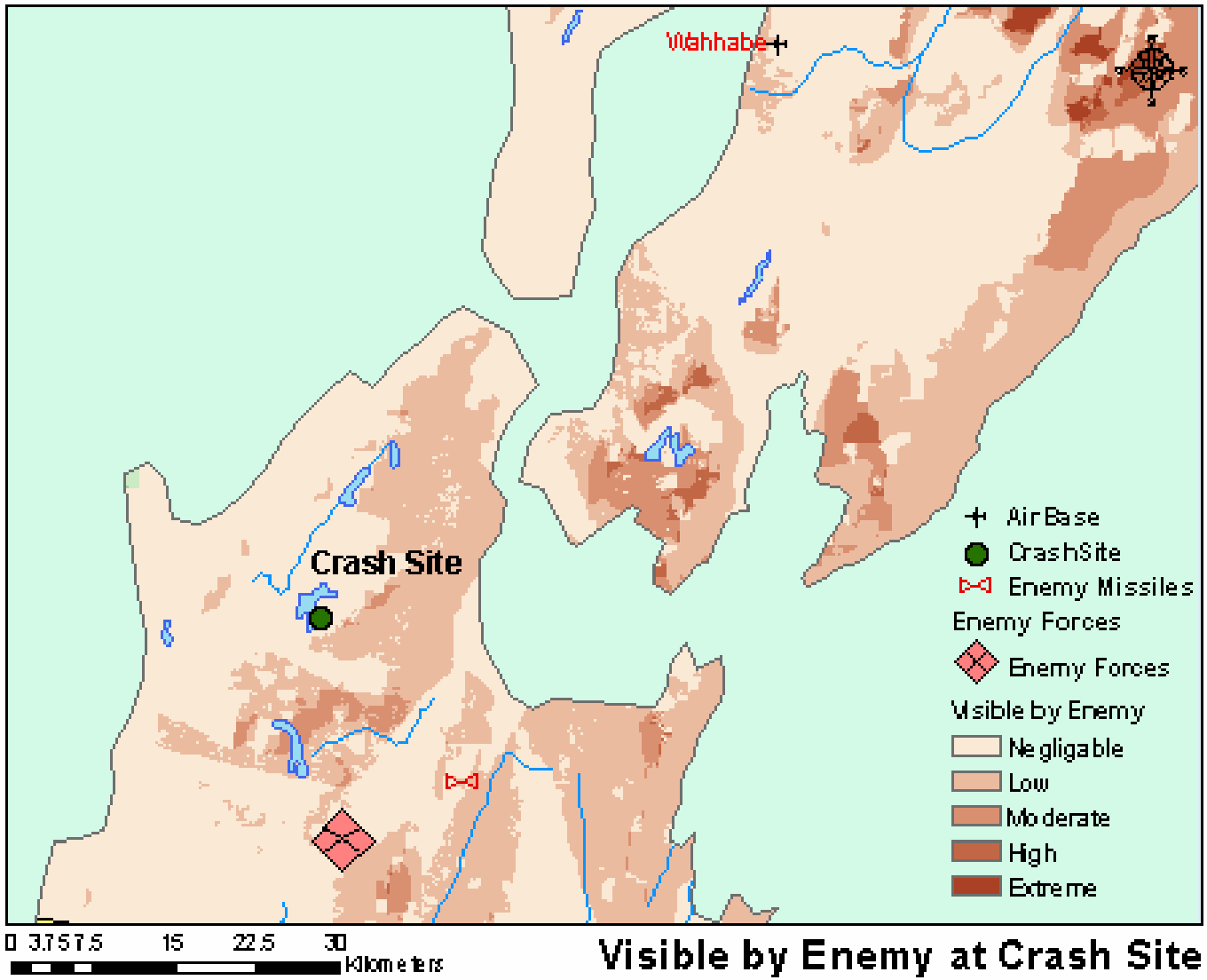
Intervisibility model





OBSNAM	OBS1	OBS2	OBS3	OBS4	OBS5	OBS6	OBS7	OBS8	OBS9
Friendly1	0	1	1	1	0	1	0	0	0
Friendly2	0	1	0	0	0	0	0	0	0
Friendly3	1	0	1	0	1	0	0	0	0
Friendly4	0	0	0	0	0	0	0	0	0
Friendly5	0	0	1	0	0	0	1	0	0
Friendly6	1	0	0	0	1	1	0	0	0
Enemy7	0	0	0	0	0	0	0	1	0
Enemy8	0	0	0	0	0	0	0	1	0
Enemy9	0	0	0	0	0	0	0	0	0

Visibility by ennemy at crash site



Formal verification of protocols

Protocol 1

Property	Result
AG $(halted \Rightarrow K_R\ r_5)$	`fails`
AG $(halted \Rightarrow r_4 \vee r_5 \vee r_6)$	`holds`
AF $halted$	`fails`

Protocol 2

Property	Result
AG $(halted \Rightarrow K_R\ r_5)$	`holds`
AF $halted$	`holds`

Conclusions

- Mathematical formalism and verification methodology for visibility-based terrain analysis and route planning.
- Integrate reasoning about visibility relations in existing SAR software (SAROPS, SARPLAN).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