Efficient Aircraft Assignment for Search and Rescue of Threatened Population in Disaster Relief Operations

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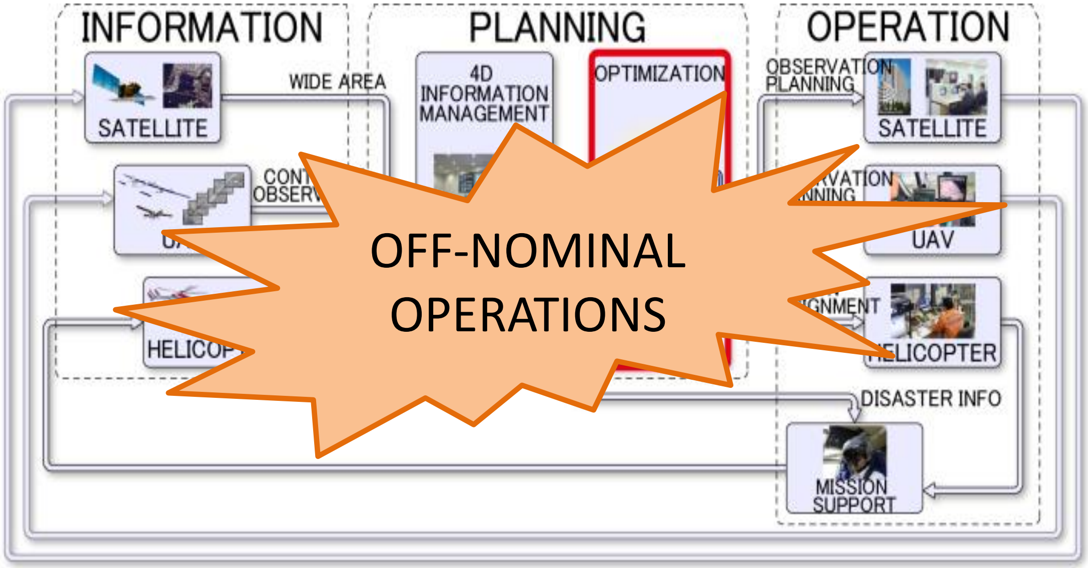
Outline: JAXA's system for disaster relief

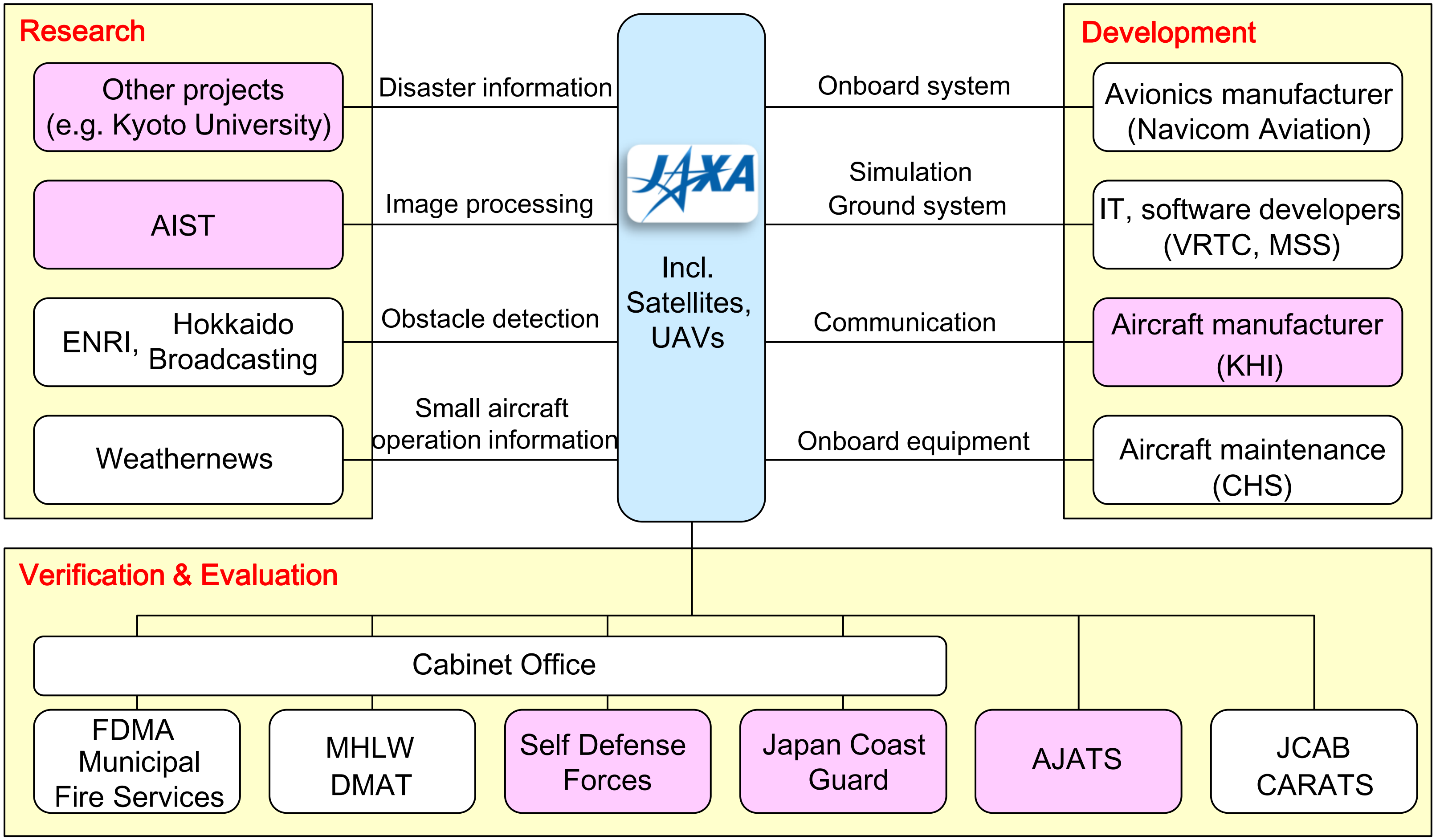
- Disaster relief
  - Efficient reconnaissance
  - Prompt planning and execution of rescue missions
- JAXA's integrated aircraft operation system for disaster relief (D-NET 2)
  - Satellites
  - Manned aircraft
  - Unmanned aircraft

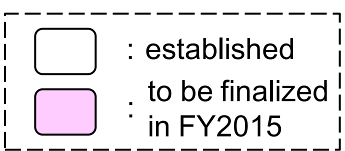
DIRECT
Search & Rescue



Collaboration with direct participants in disaster relief

Collaboration





AIST: National Institute of Advanced Industrial Science and Technology
AJATS: All Japan Air Transport and Service Association
CARATS: Collaborative Actions for Renovation of Air Traffic Systems
CHS: Central Helicopter Service
DMAT: Japan Disaster Medical Assistance Team
ENRI: Electronic Navigation Research Institute
FDMA: Fire and Disaster Management Agency
JCAB: Japan Civil Aviation Bureau
KHI: Kawasaki Heavy Industries
MHLW: Ministry of Health, Labour and Welfare
MSS: Mitsubishi Space Software
VRTC: VR Techno Center

System properties and requirements

- Enable safe and efficient operations
- Test concepts and strategies
- Demonstrate operations
  - Numerical simulations
  - Disaster drills
- Require partnerships
  - Fire departments
  - Disaster medical assistance teams
  - Industry

- Predict and manage congestions
- Handle heterogeneous vehicles

Search and rescue flow

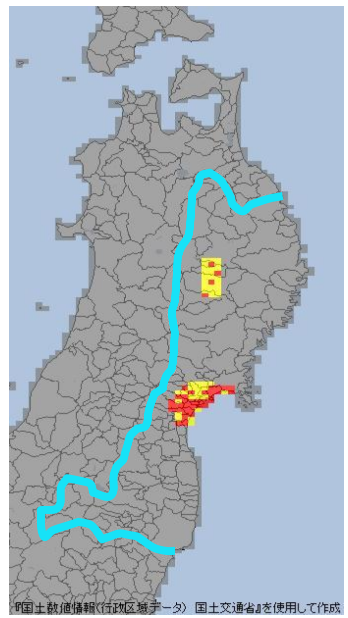
Search (reconnaissance)

rescue

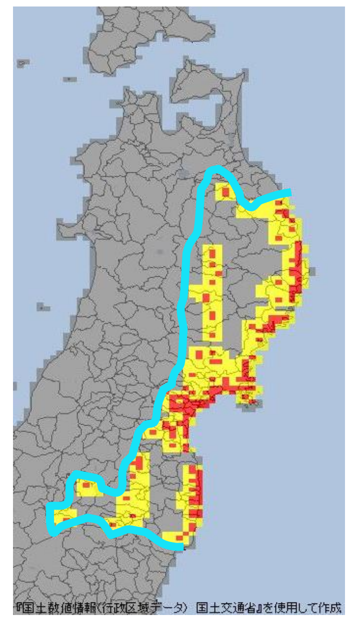
logistics, road reconstruction,etc.

QOL=1 unknown	QOL=2 life in danger	QOL=3 emergency goods needed	QOL=4 full recovery

right after
the earthquake
(March 11, 14:46)



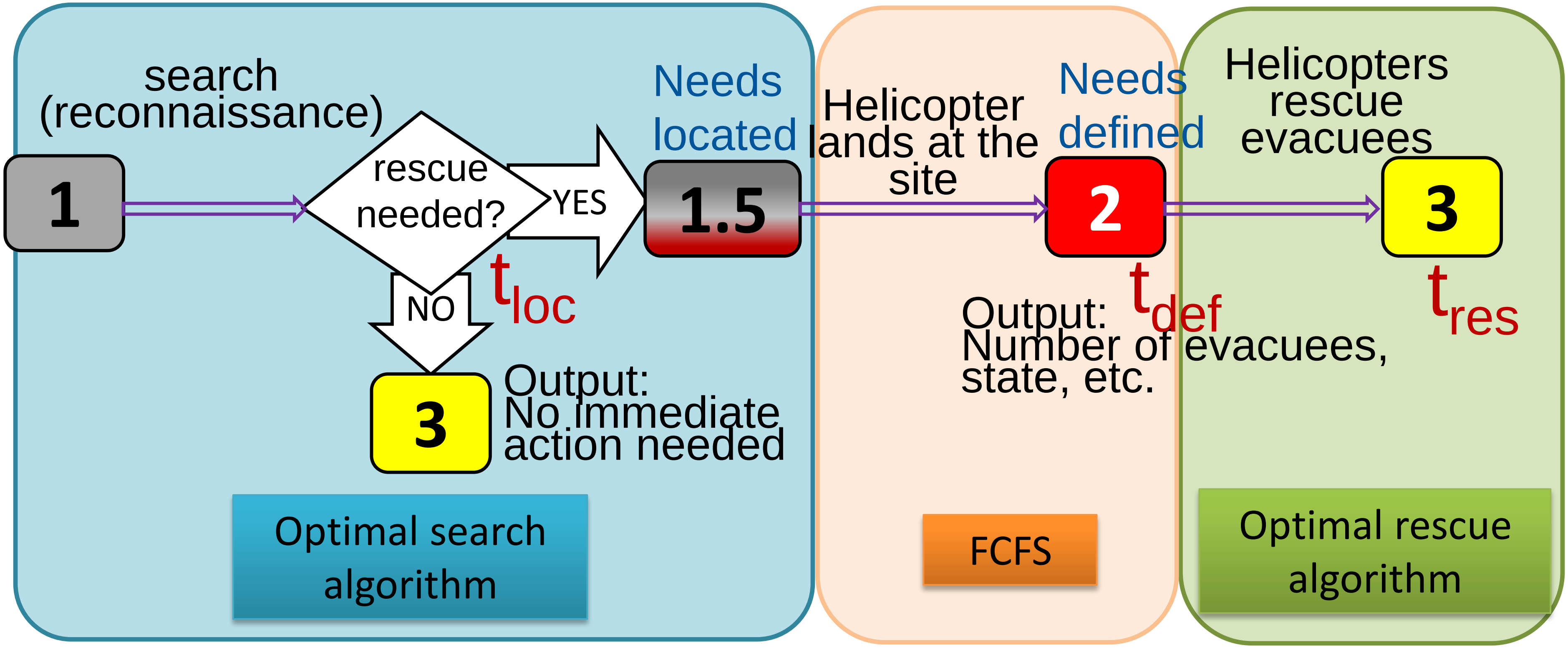
16 h later
（March 12, 6:46）



20 h later
（March 12, 10:46）

*QOL: Quality of Life

Current research scope

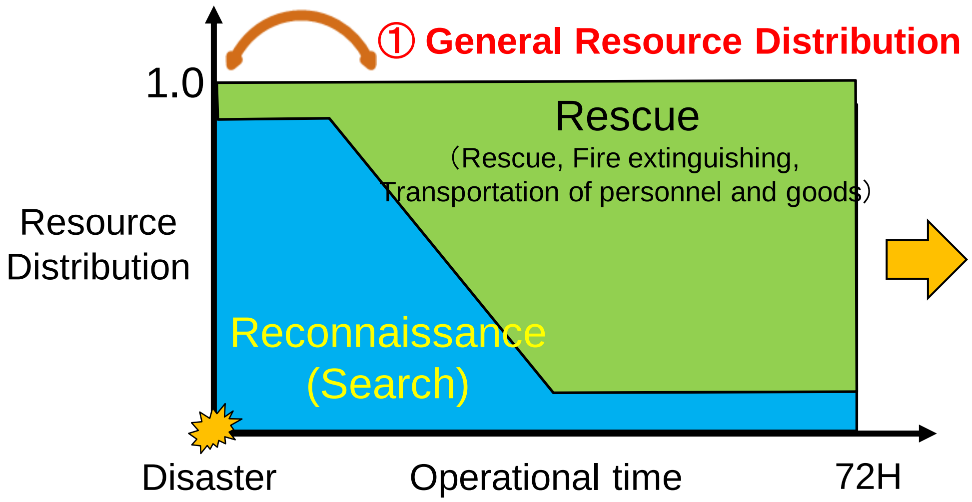


Main constraints

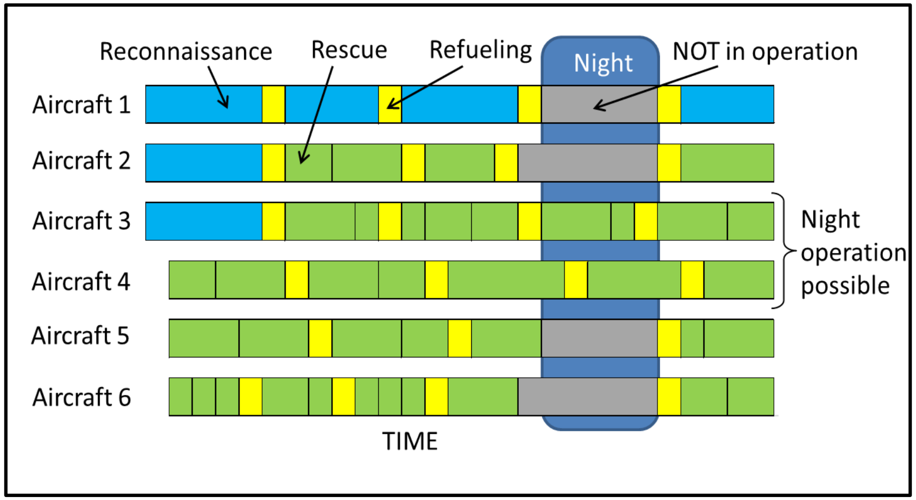
- Hard time limit t_{lim} = 72 h
- Aircraft performance constraints
- Total number of aircraft

Problem formulation

Search & Rescue



Output



② Reconnaissance (Search)

Focus	Satellite, UAV & manned aircraft
Problem Setting	(Grid World) Exploration
Sample Method	Hybrid GA (under development)

③ Rescue

Focus	Real-time, multiple constraints optimization
Problem Setting	Scheduling
Sample Method	Hybrid PSO (under development)

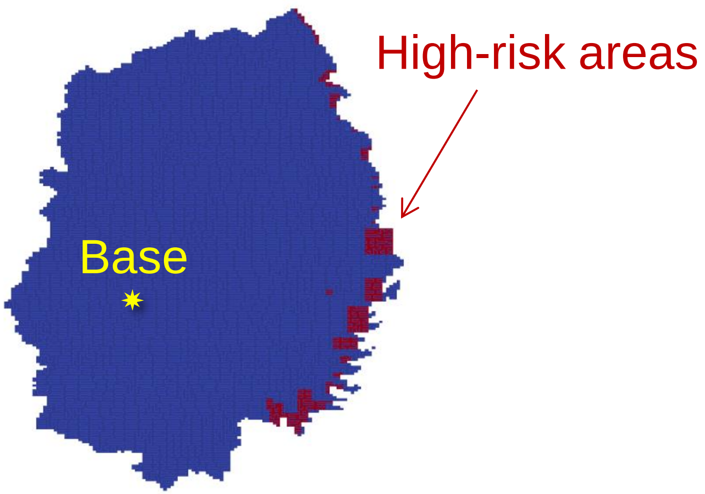
I. The best general resource distribution?

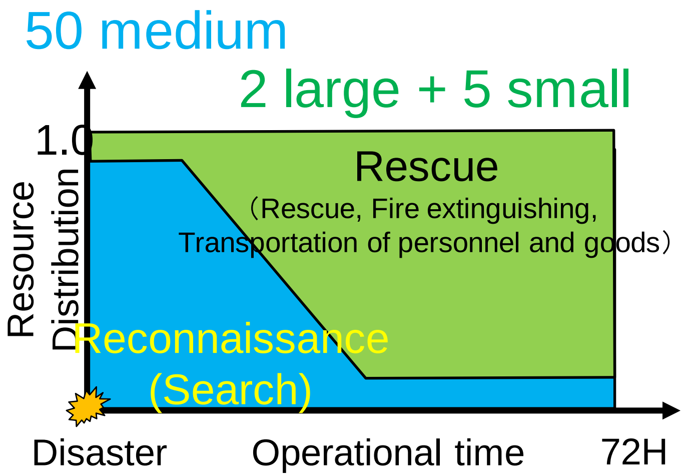
II. Resources vs. necessary time

III. Sufficient resources?

Simulation assumptions (preliminary)

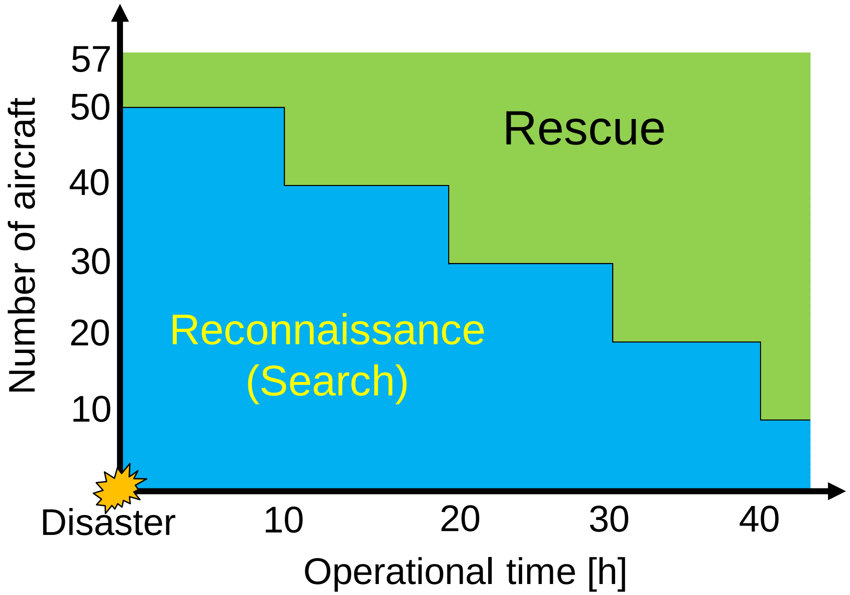
- Iwate Prefecture (2^{nd} largest in Japan, 15,280 km^2)
- Manned aircraft only
- One helicopter base
- Continuous operations
  (72 h→ 42 h)
- Available aircraft
- Aircraft operational constraints
  - Maximum fuel constraint
    (flight range 2.5 h - 3.5 h)
  - Refuel time 20 (30) min
  - Passengers capacity: 5, 14, 25



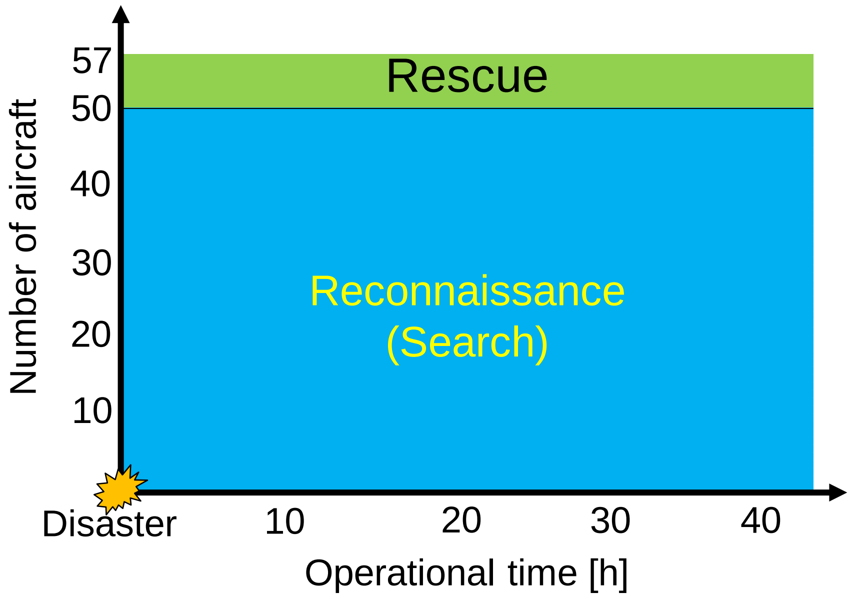


Simulation cases

I. Search aircraft 50→40…10



II. Search aircraft 50 (const)



<u>Goal</u>

- Search the whole disaster area ASAP
- Transport all evacuees to the base ASAP

Search Optimization Results (Example)

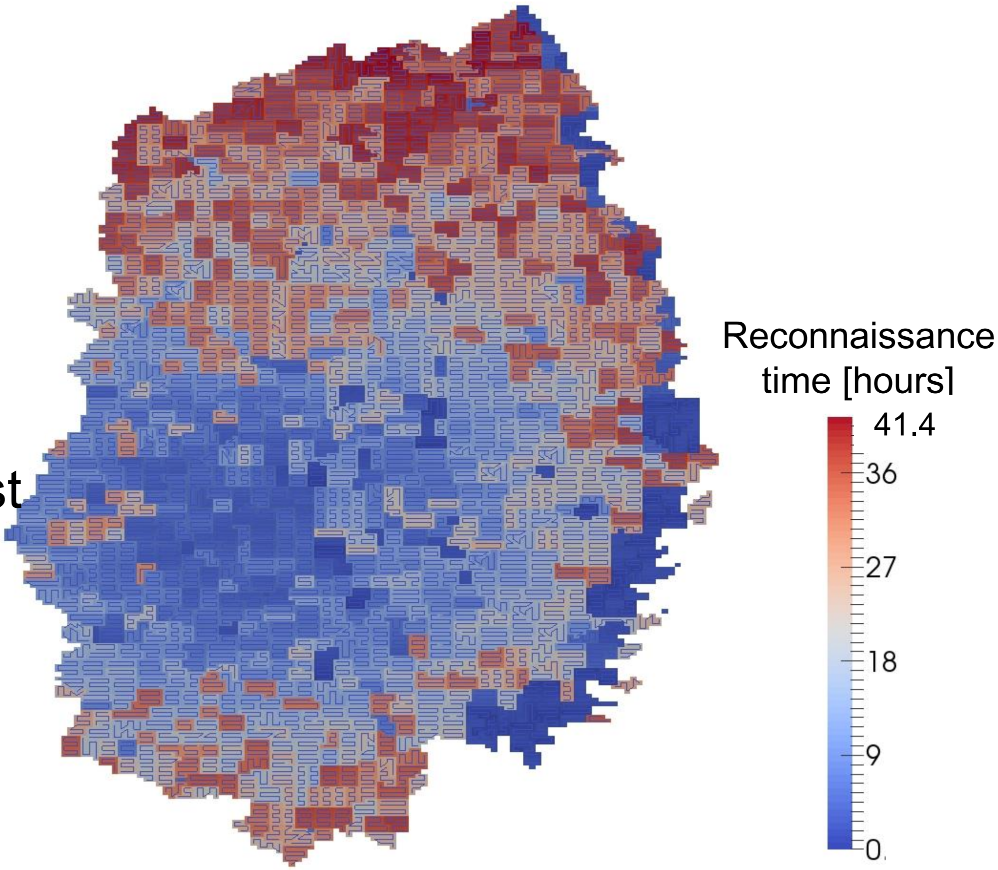
II. Search aircraft 50 (const)

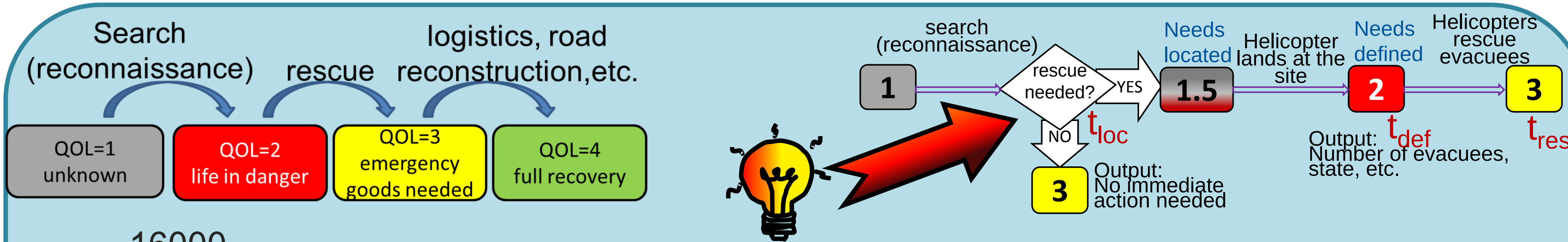
- Cluster-based algorithm
- Adjustments for operational constraints
- Cell priority!
- Flight routes also generated
- Very fast computation

  (less than a minute)
- Routes might vary,

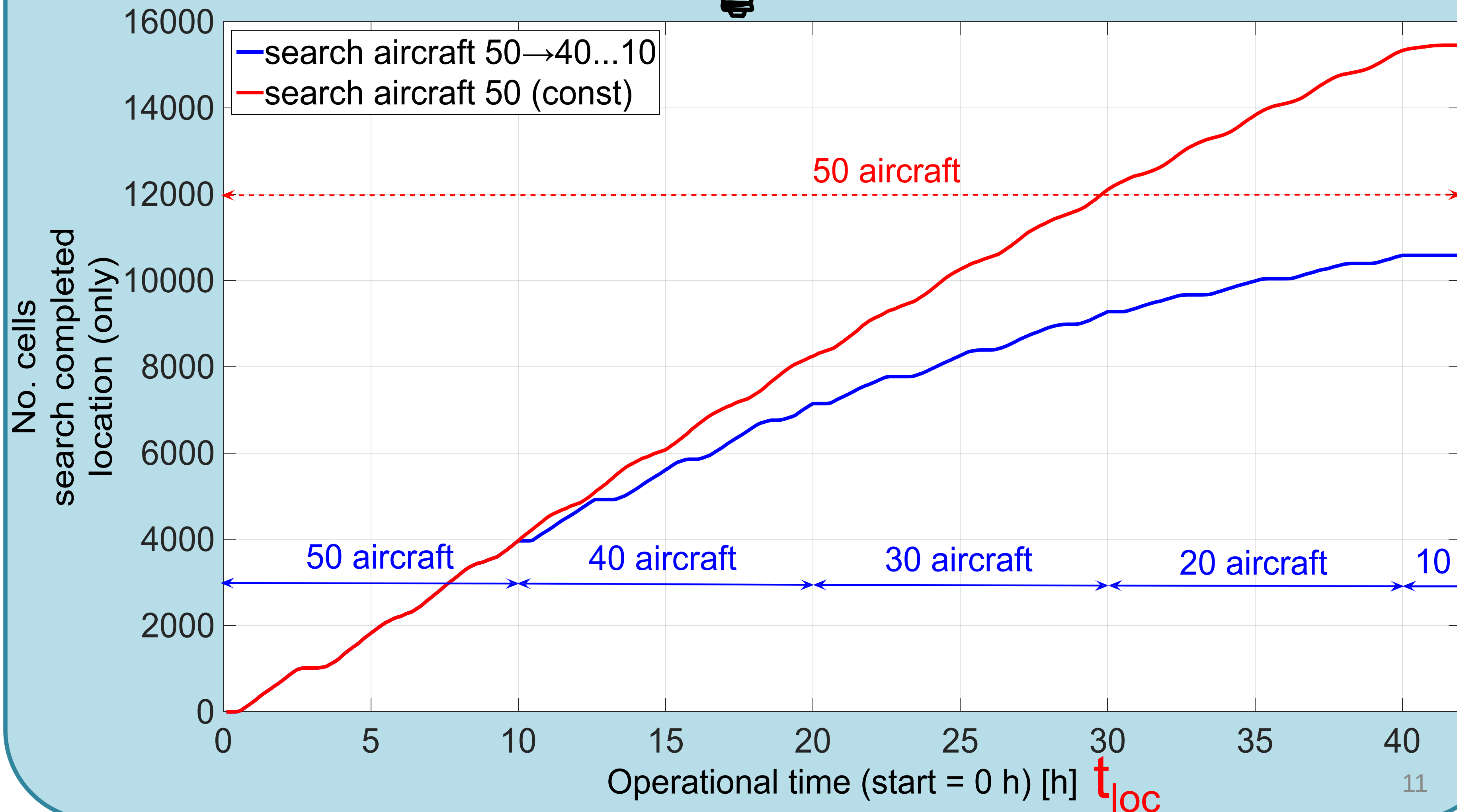
  but reconnaissance time is robust

→ strategic planning

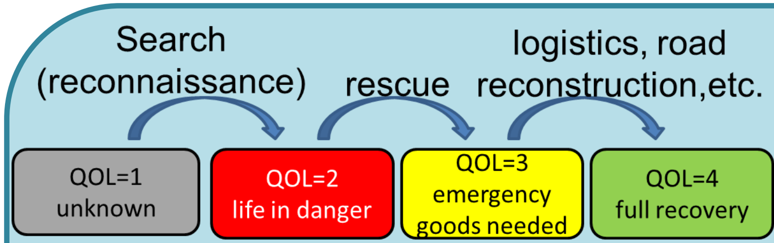




Search (reconnaissance)
rescue
logistics, road reconstruction,etc.
QOL=1 unknown
QOL=2 life in danger
QOL=3 emergency goods needed
QOL=4 full recovery
search (reconnaissance)
1
rescue needed?
YES
NO
t_{loc}
3
Output: No immediate action needed
Needs located
1.5
Helicopter lands at the site
Needs defined
2
t_{def}
Output: Number of evacuees, state, etc.
Helicopters rescue evacuees
3
t_{res}



search aircraft 50→40...10
search aircraft 50 (const)
50 aircraft
50 aircraft
40 aircraft
30 aircraft
20 aircraft
10
No. cells search completed location (only)
0
2000
4000
6000
8000
10000
12000
14000
16000
0
5
10
15
20
25
30
35
40
Operational time (start = 0 h) [h]
t_{loc}



Search (reconnaissance)
rescue
logistics, road reconstruction,etc.
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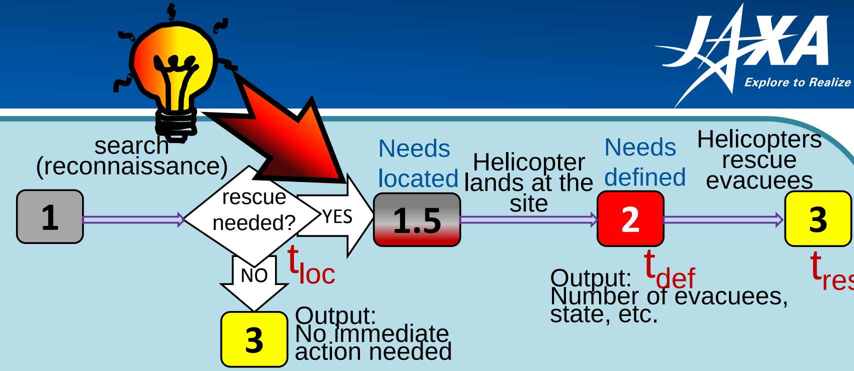

search (reconnaissance)
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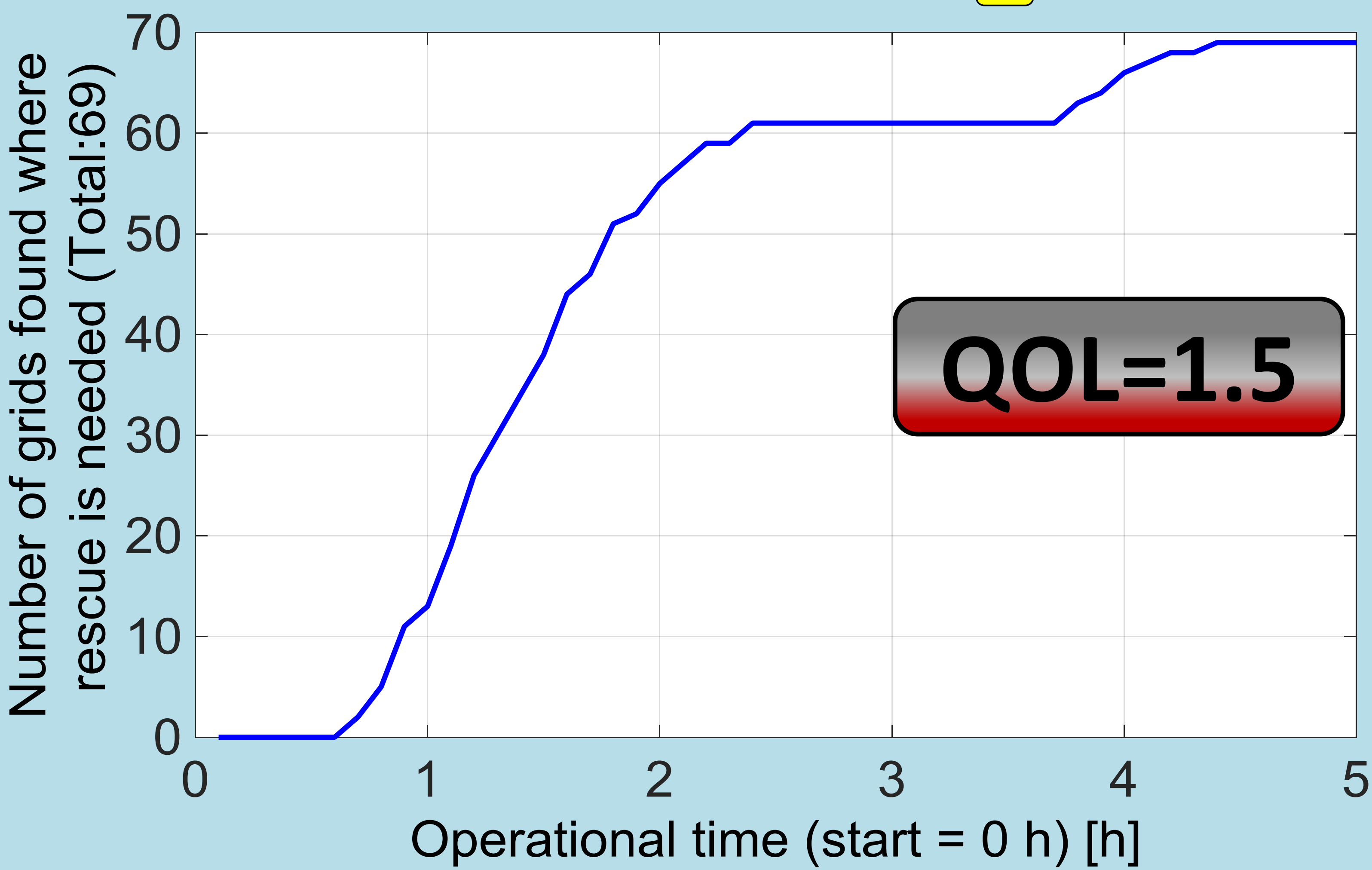
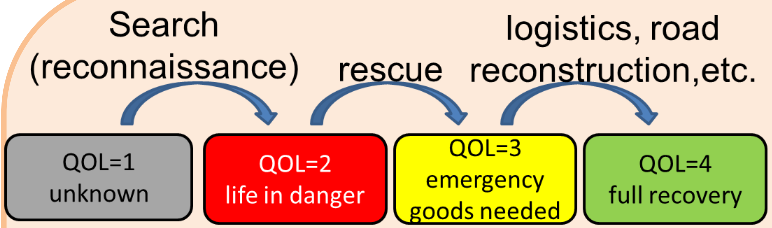
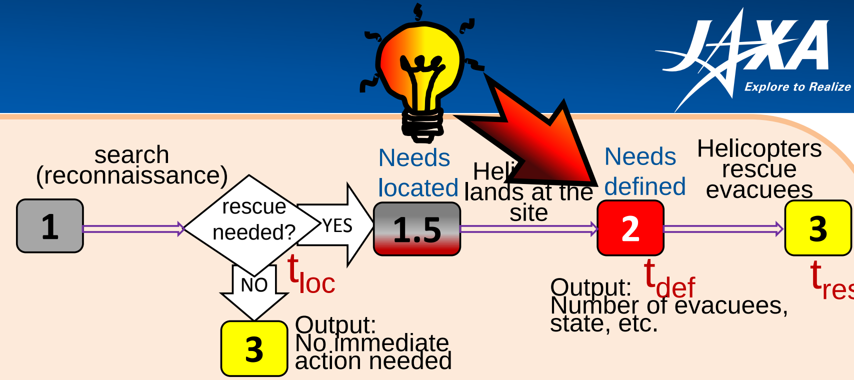


Number of grids found where rescue is needed (Total:69)
0
10
20
30
40
50
60
70
0
1
2
3
4
5
Operational time (start = 0 h) [h]
QOL=1.5


Search
(reconnaissance)
rescue
logistics, road
reconstruction,etc.
QOL=1
unknown
QOL=2
life in danger
QOL=3
emergency
goods needed
QOL=4
full recovery


search
(reconnaissance)
1
rescue
needed?
YES
NO
t_{loc}
3
Output:
No immediate
action needed
Needs
located
1.5
Heli
lands at the
site
Needs
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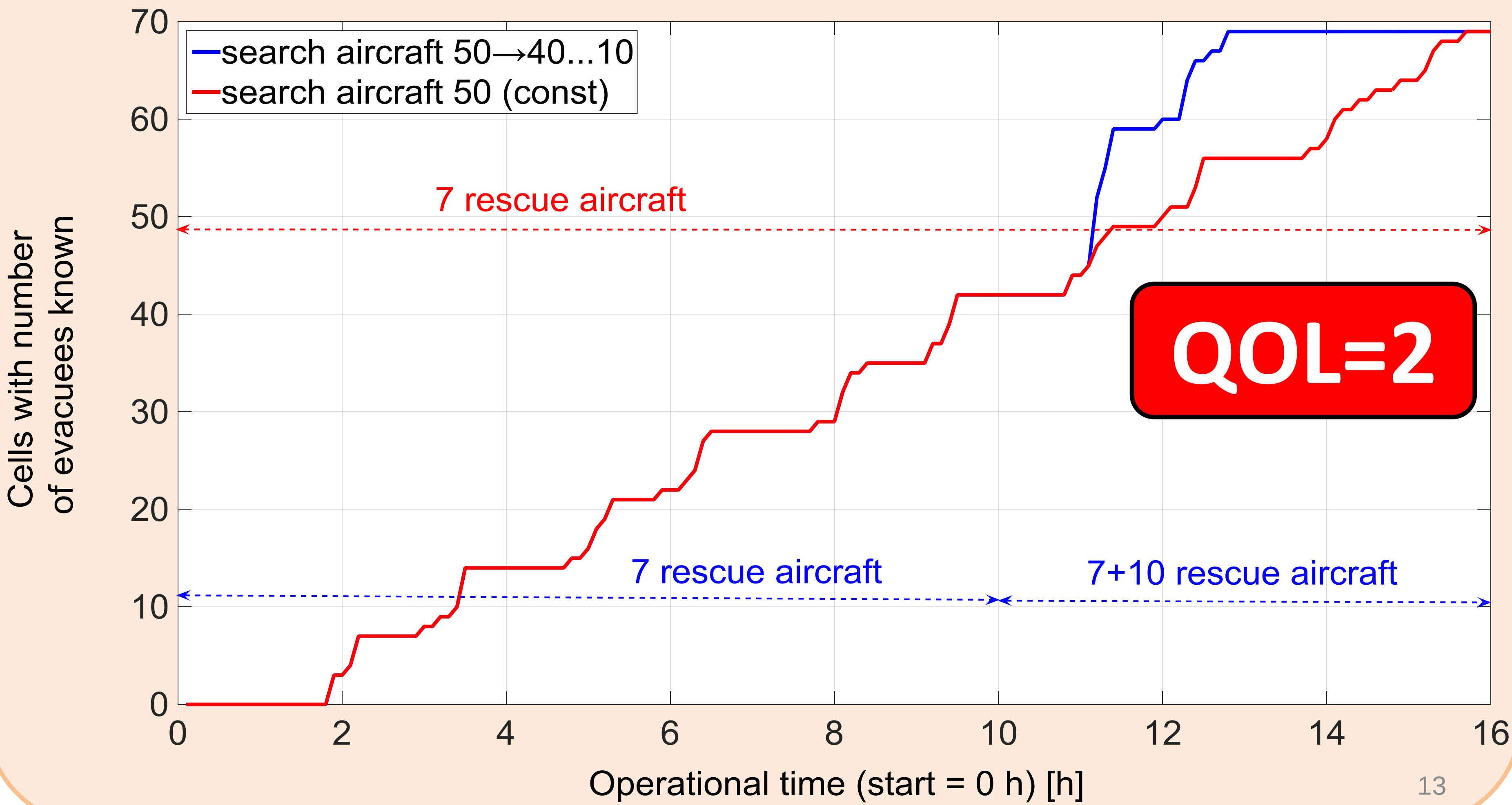
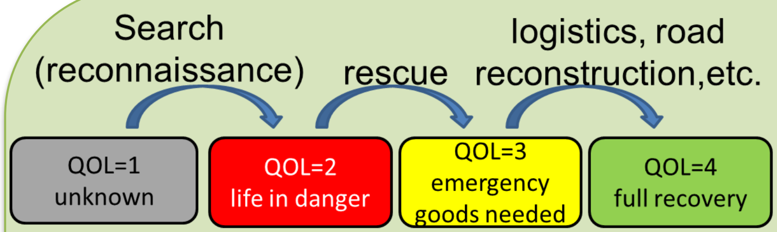
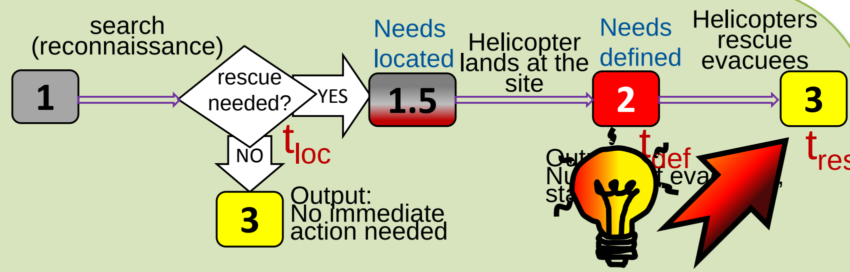
2
t_{def}
Output:
Number of evacuees,
state, etc.
Helicopters
rescue
evacuees
3
t_{res}


search aircraft 50→40...10
search aircraft 50 (const)
7 rescue aircraft
7 rescue aircraft
7+10 rescue aircraft
QOL=2
Cells with number
of evacuees known
Operational time (start = 0 h) [h]
0
10
20
30
40
50
60
70
0
2
4
6
8
10
12
14
16


Search
(reconnaissance)
rescue
logistics, road
reconstruction,etc.
QOL=1
unknown
QOL=2
life in danger
QOL=3
emergency
goods needed
QOL=4
full recovery


search
(reconnaissance)
1
rescue
needed?
YES
NO
t_{loc}
3
Output:
No immediate
action needed
Needs
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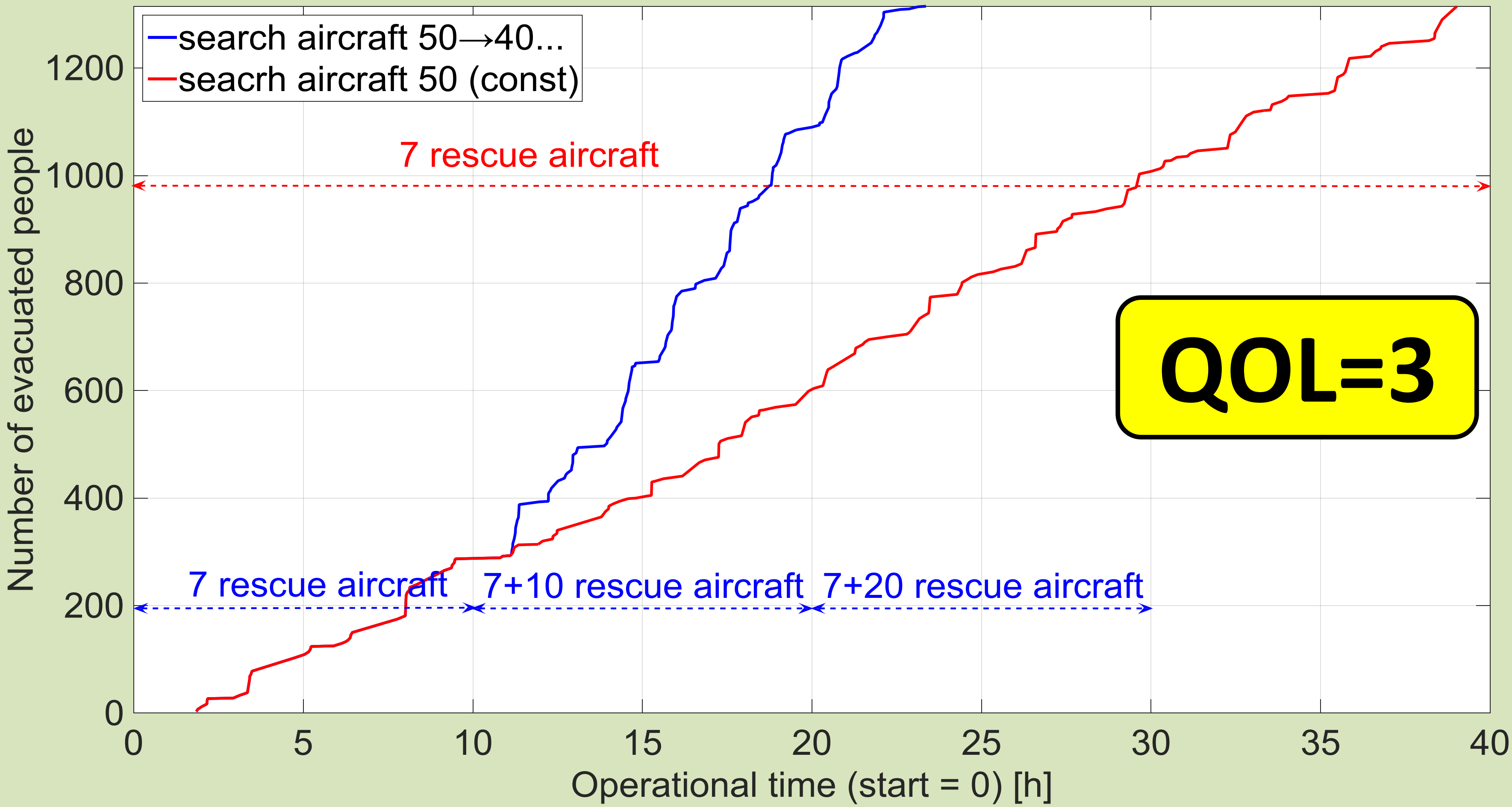
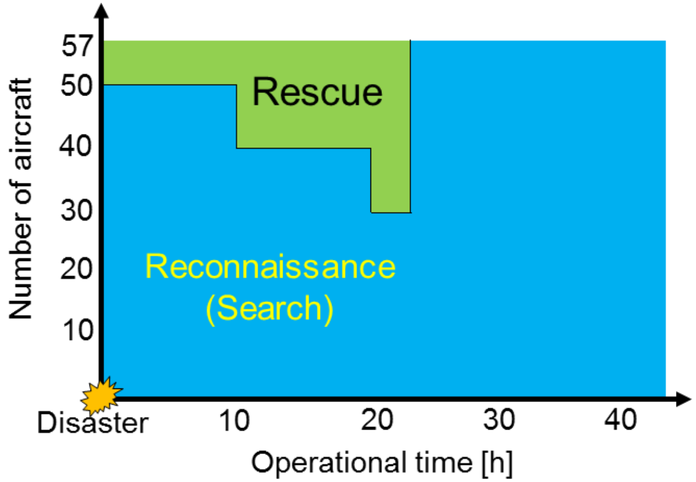
1.5
Helicopter
lands at the
site
Needs
defined
2
t_{def}
Helicopters
rescue
evacuees
3
t_{res}


search aircraft 50→40...
seacrh aircraft 50 (const)
7 rescue aircraft
7 rescue aircraft
7+10 rescue aircraft
7+20 rescue aircraft
QOL=3
Number of evacuated people
Operational time (start = 0) [h]
0
200
400
600
800
1000
1200
0
5
10
15
20
25
30
35
40

Result Analysis

- In reality, less than 50 search aircraft
  - UAV can be the key
- Accurate prediction of needs location
  - “uncertainties” considered in new simulation
- Resource allocation curve is more complicated than expected
  - Dependence on disaster scenario
  - More scenarios being considered
- <u>Multi-objective optimization</u>



Conclusions

- Overall estimation of search and rescue time
- Successful aircraft assignment
- Fast real-time simulation → strategic planning
- New insights into resource allocation

Future work

- More practical constraints
- Other scenarios
- Uncertainties
- Multi-objective optimization (Pareto solution)