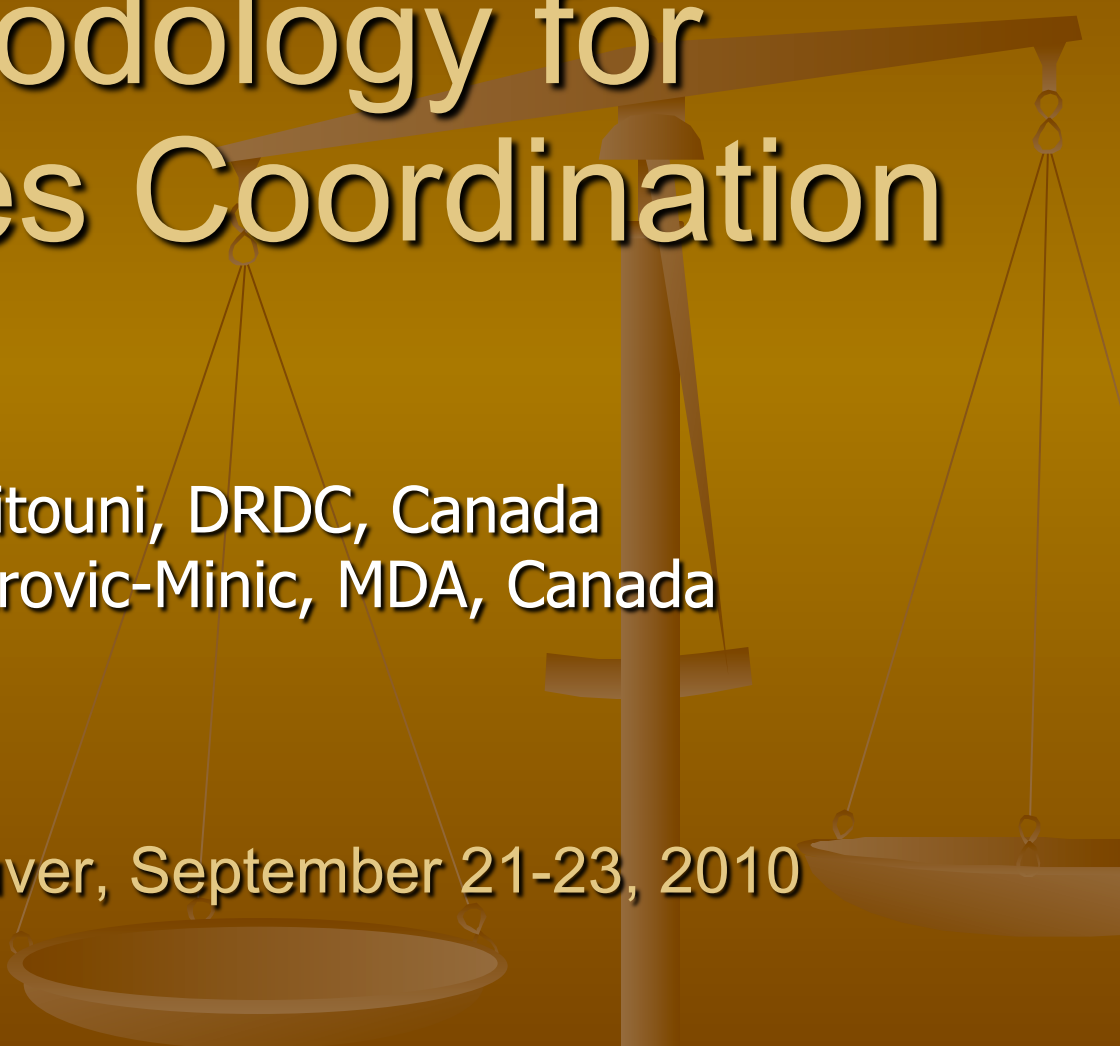


# Risk Aggregation Methodology for Joint Fires Coordination



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KSCO, Vancouver, September 21-23, 2010

# Outline

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- Motivation
- Introduction
- Where aggregation is required?
- Our methodology
- Applications

# Motivation

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- Research on risk aggregation is **scarce**
- **Risk aggregation** methodologies for joint operations
  - mission planning and
  - plan execution

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## What is Risk?

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**Risk** is the expression of the **likelihood** and **impact** of an event with the potential to influence the achievement of an organization's objectives [Treasury Board Canada Secretariat 2001]

# Thick Snow Cover and Construction Work Requiring Explosives



Risk Evaluation Matrix						
		Probability				
Severity		Frequent A	Probable B	Occasional C	Rare D	Improbabl e E
Catastrophic	I	EH	EH	H	H	M
Critical	II	EH	H	H	M	L
Marginal	III	H	M	M	L	L
Negligible	IV	M	L	L	L	L

# Thick Snow Cover and Construction Work Requiring Explosives



Risk Evaluation Matrix

		Probability				
Severity		Frequent A	Probable B	Occasional C	Rare D	Improbabl e E
Catastrophic	I	EH	<b>EH</b>	H	H	M
Critical	II	EH	H	H	M	L
Marginal	III	H	M	M	L	L
Negligible	IV	M	L	L	L	L

# What is Risk Management?

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- Risk management is a **systematic approach** to setting the **best course of action** under uncertainty by identifying, assessing, understanding, acting on, and communicating risk issues [Treasury Board Canada Secretariat 2001]
- Risk management is **crucial** for effective joint decision making to enhance operational capabilities and mission accomplishment, with minimal acceptable loss



# Risk Management

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## Principles:

- Accept No Unnecessary Risk
- Make Risk Decisions at the Appropriate Level
- Anticipate and Manage Risk by Planning

# Risk Management

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- Accept No Unnecessary Risk
- **Make Risk Decisions at the Appropriate Level**
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## Needed:

- Proper communication of risk information

# Risk Management

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**→ Risk aggregation**

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## In Joint Operations, Risk Aggregation is Needed Due to:

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- Risk-related information is collected from **diverse sources**
- Different risk **categories**
- Aggregation of risk through command structure because:

Risk information are **collected** at lower level of command and **decisions** are made at higher level of command

# Outline

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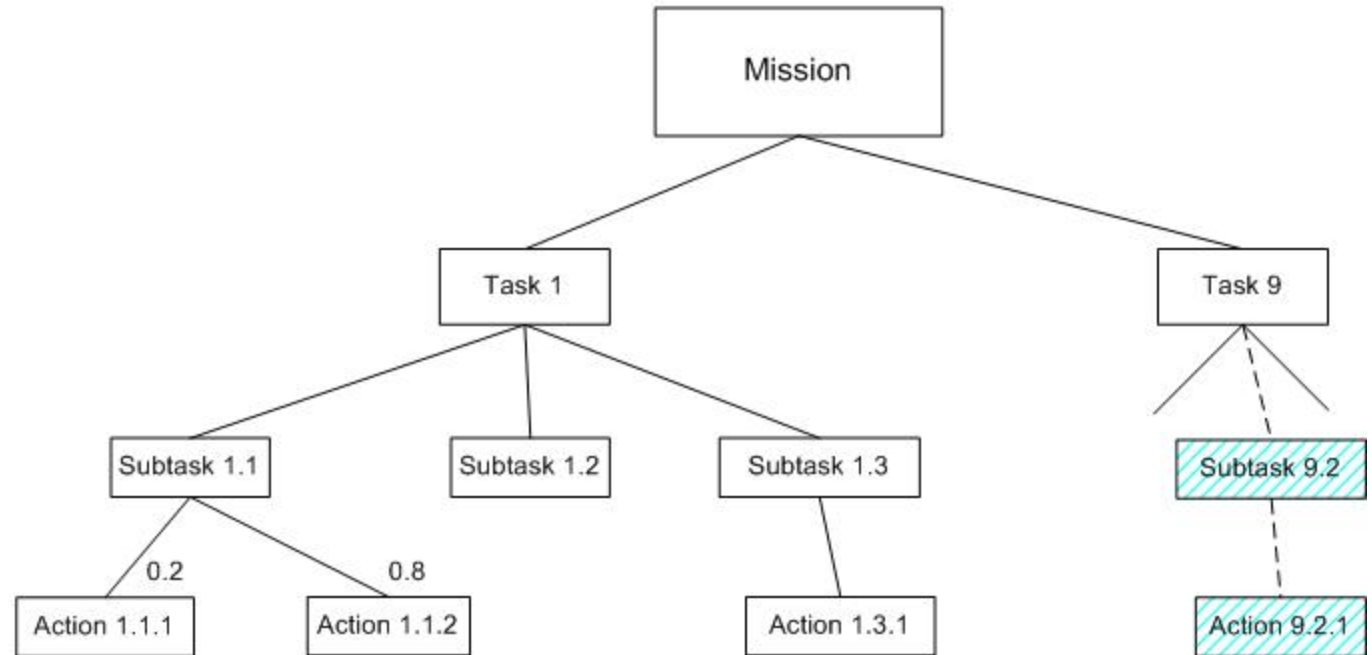
- Motivation
- Introduction
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# Our methodology

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- (S1) Generate a tree-like graph representing a **Mission Decomposition Structure (MDS)** dividing the mission in tasks, subtasks, and actions;
- (S2) Determine the importance weights for the edges of the MDS (representing **importance** of a success of a child node to a success of the parent node);
- (S3) For each **action/task**, identify associated **risks**; and
- (S4) For each risk, identify its core factors and generate corresponding Bayesian network, influence diagram, **Expanded Bayesian Network (EBN)** or **Expanded Influence Diagram (EID)** combining Dempster-Shaffer methodology and influence diagram

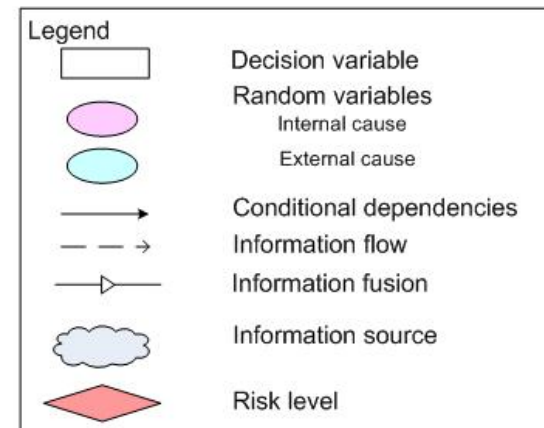
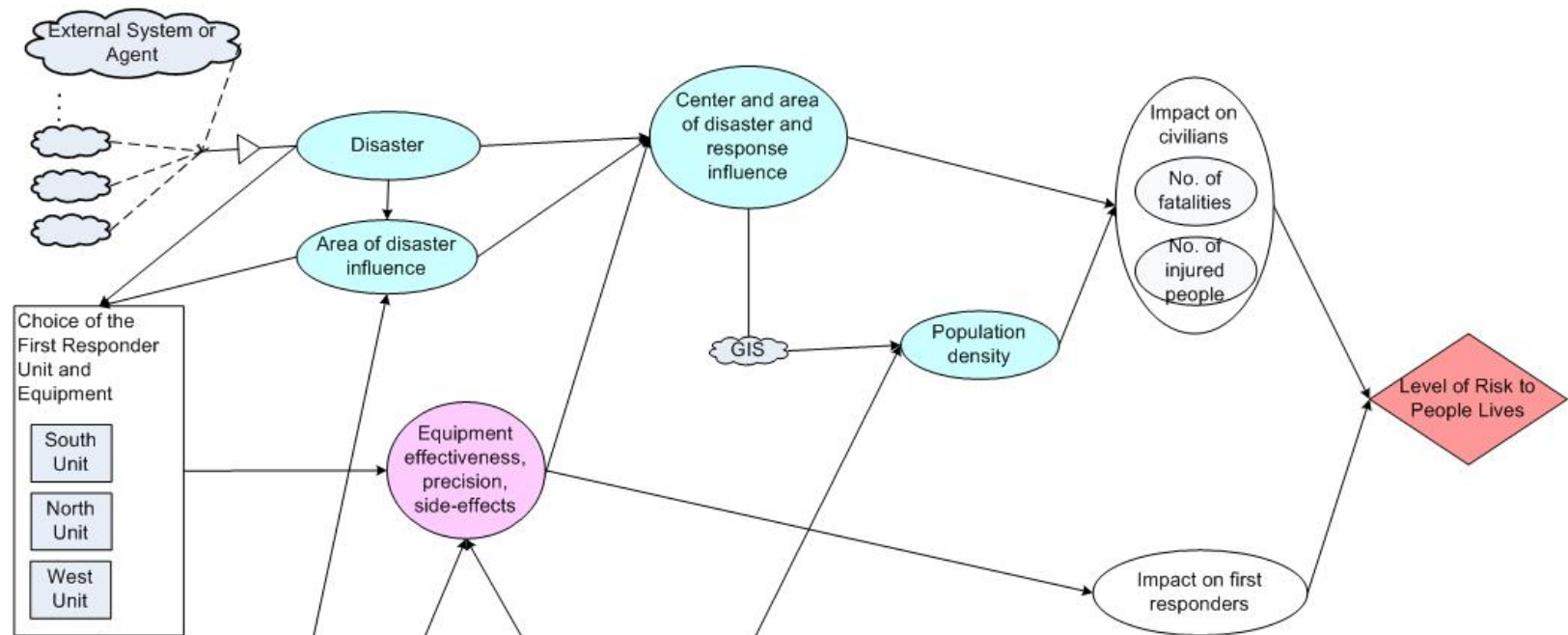
# Mission Decomposition Structure (MDS)



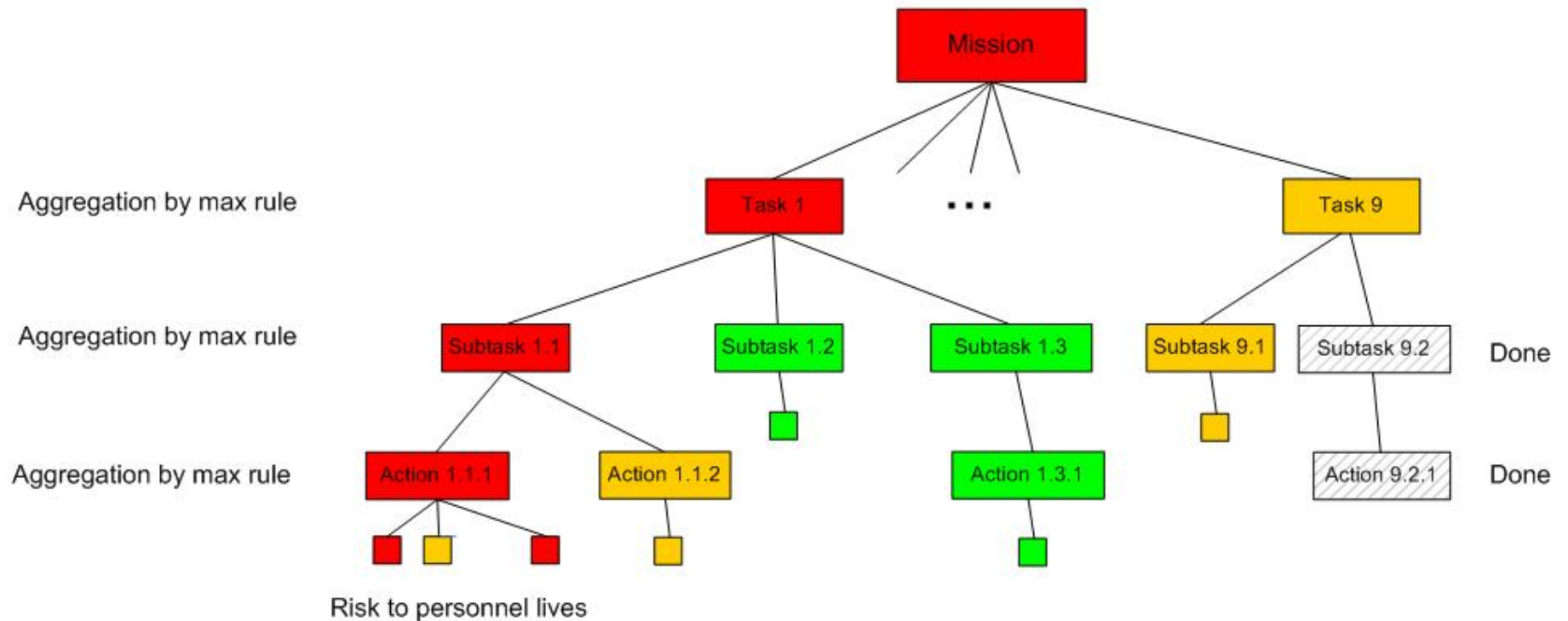


# Expanded Influence Diagram

Disaster and post-disaster effects: Combination of influence diagram and Dempster-Shafer for risk assessment



# Mission Decomposition Structure (MDS) and Risk to Personnel Lives

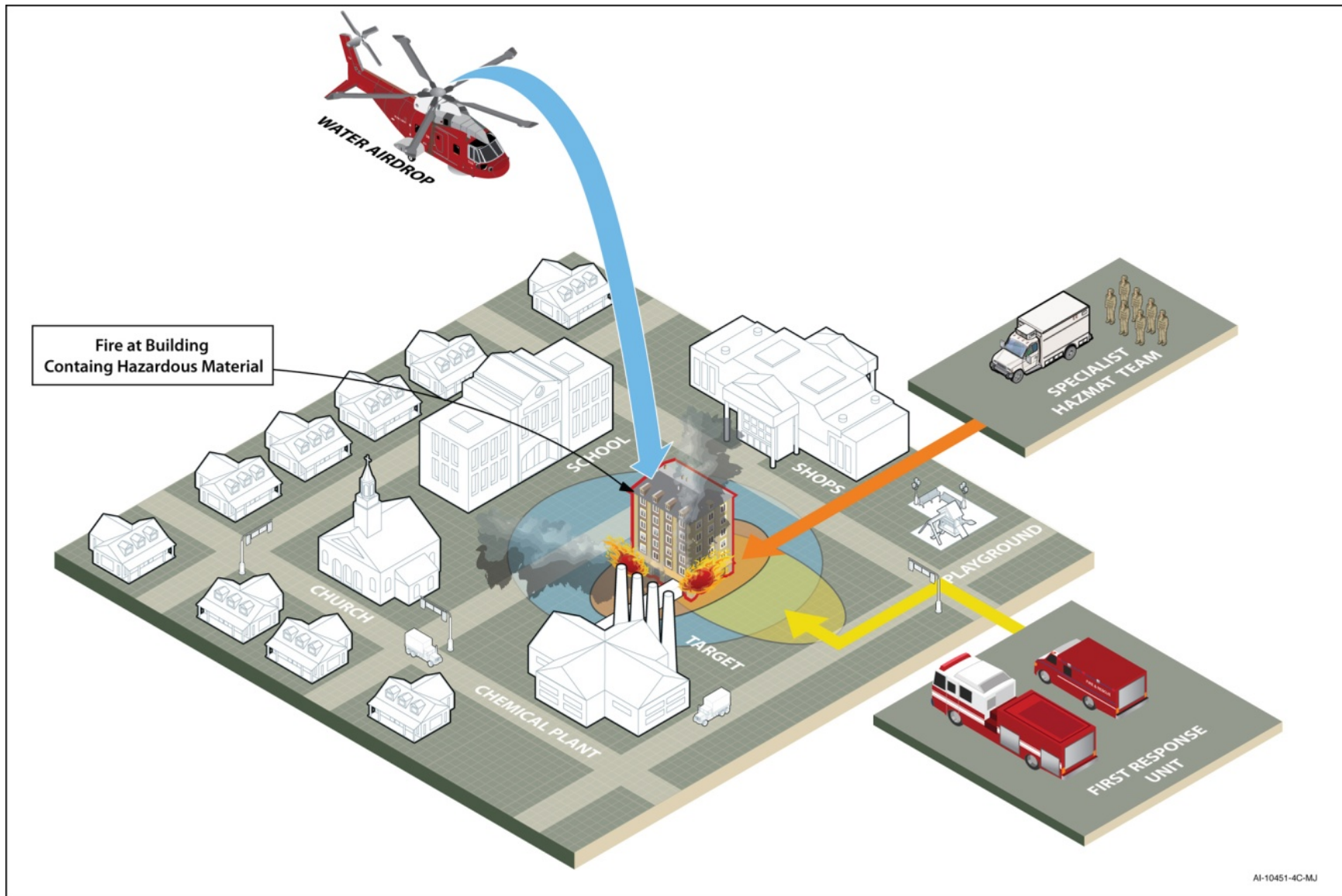


# Outline

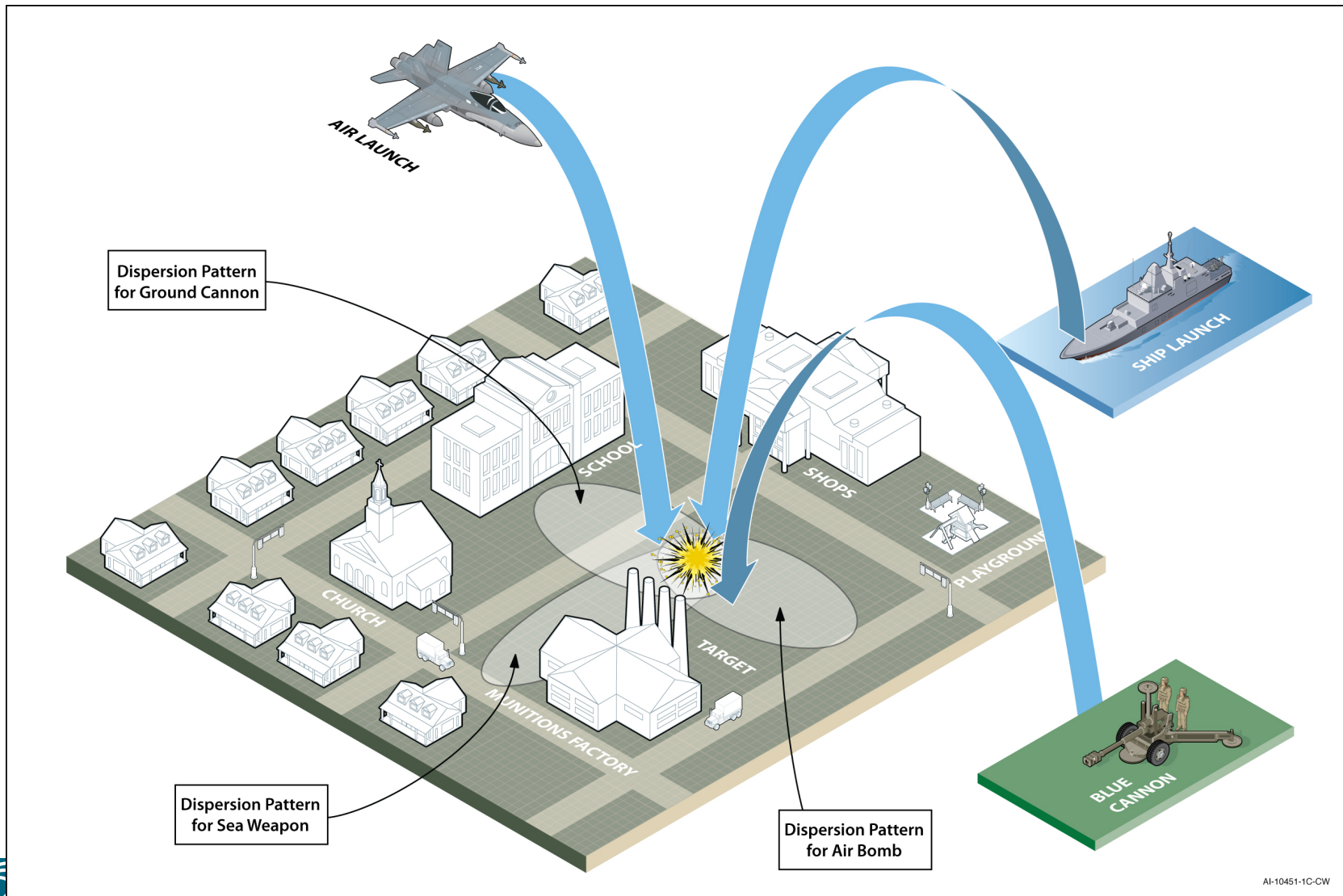
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- Motivation
- Introduction
- Problems requiring aggregation
- Potential solutions
- Application

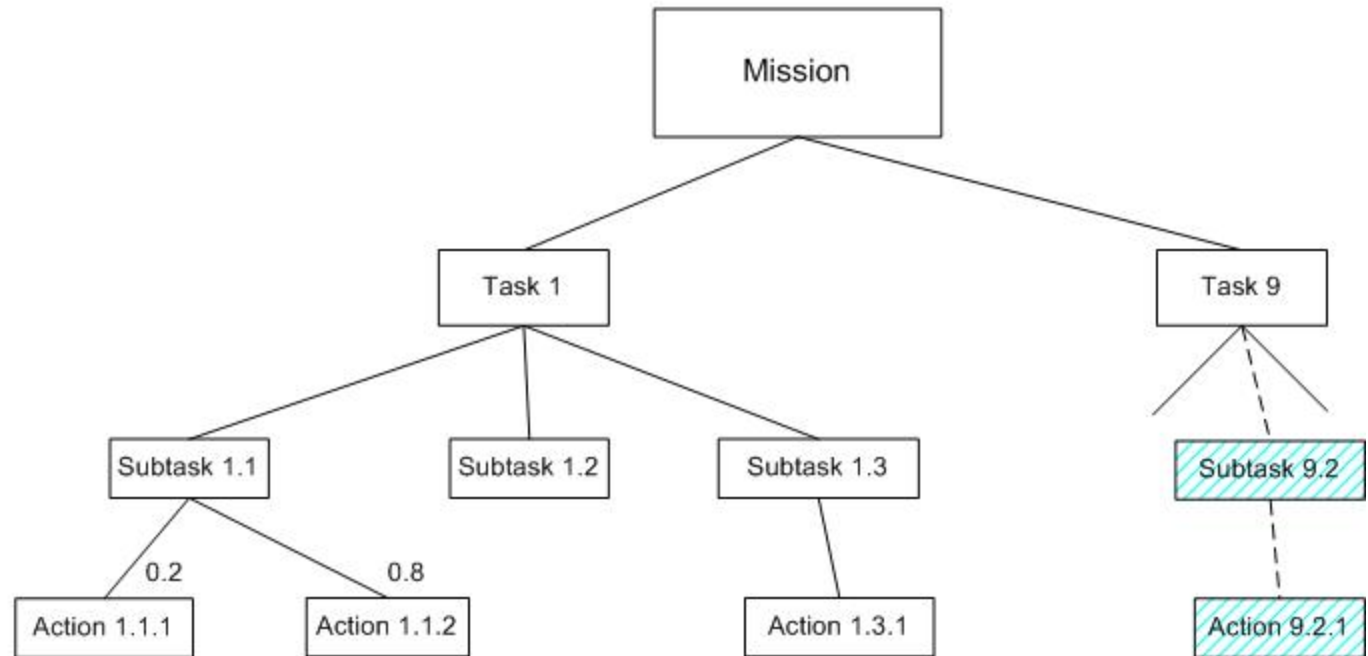
# The Intervention Plan for Fire Scenario



# Joint Fires Coordination in Urban Environment



# Mission Decomposition Structure (MDS)



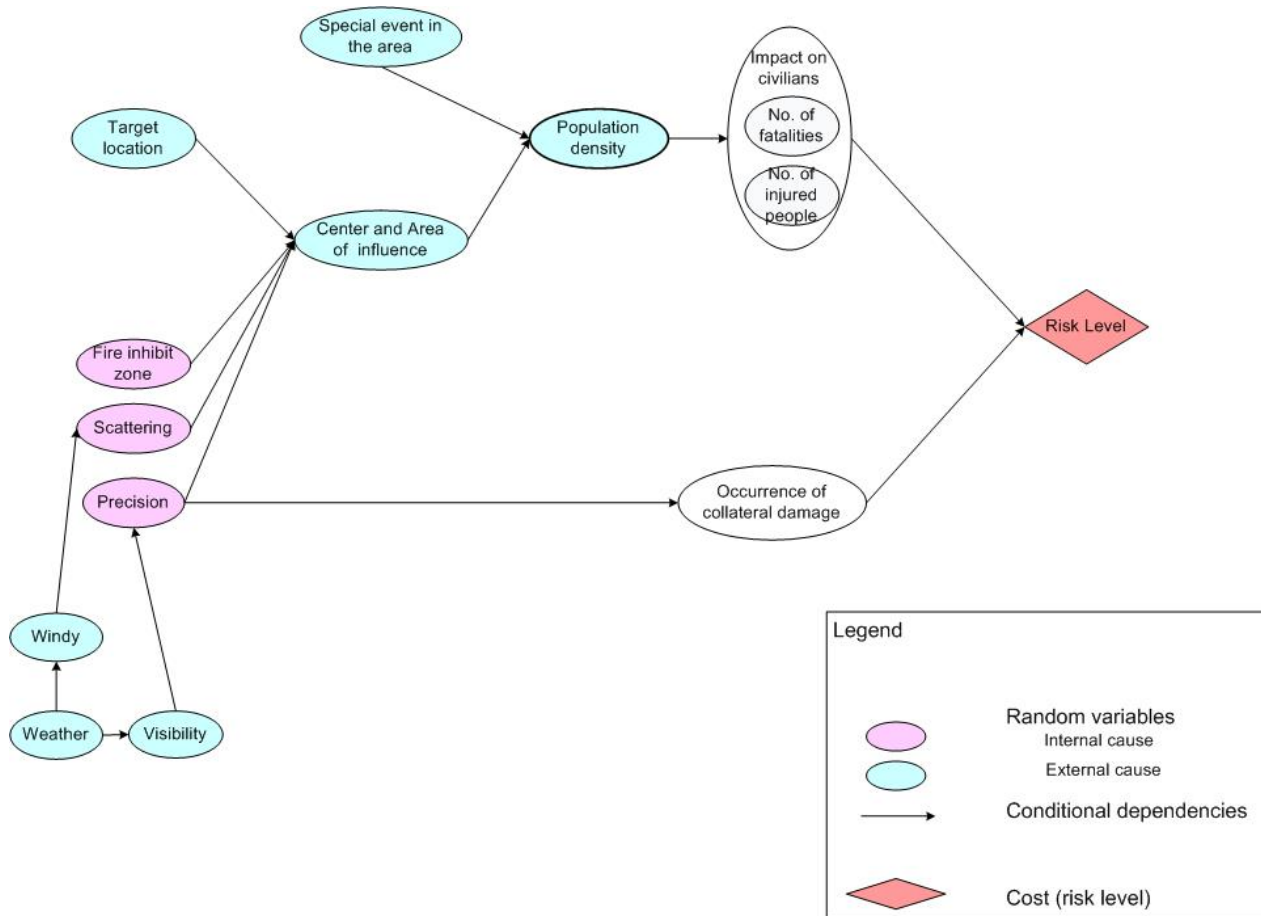
# Risk Categories

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Relevant to joint operations:

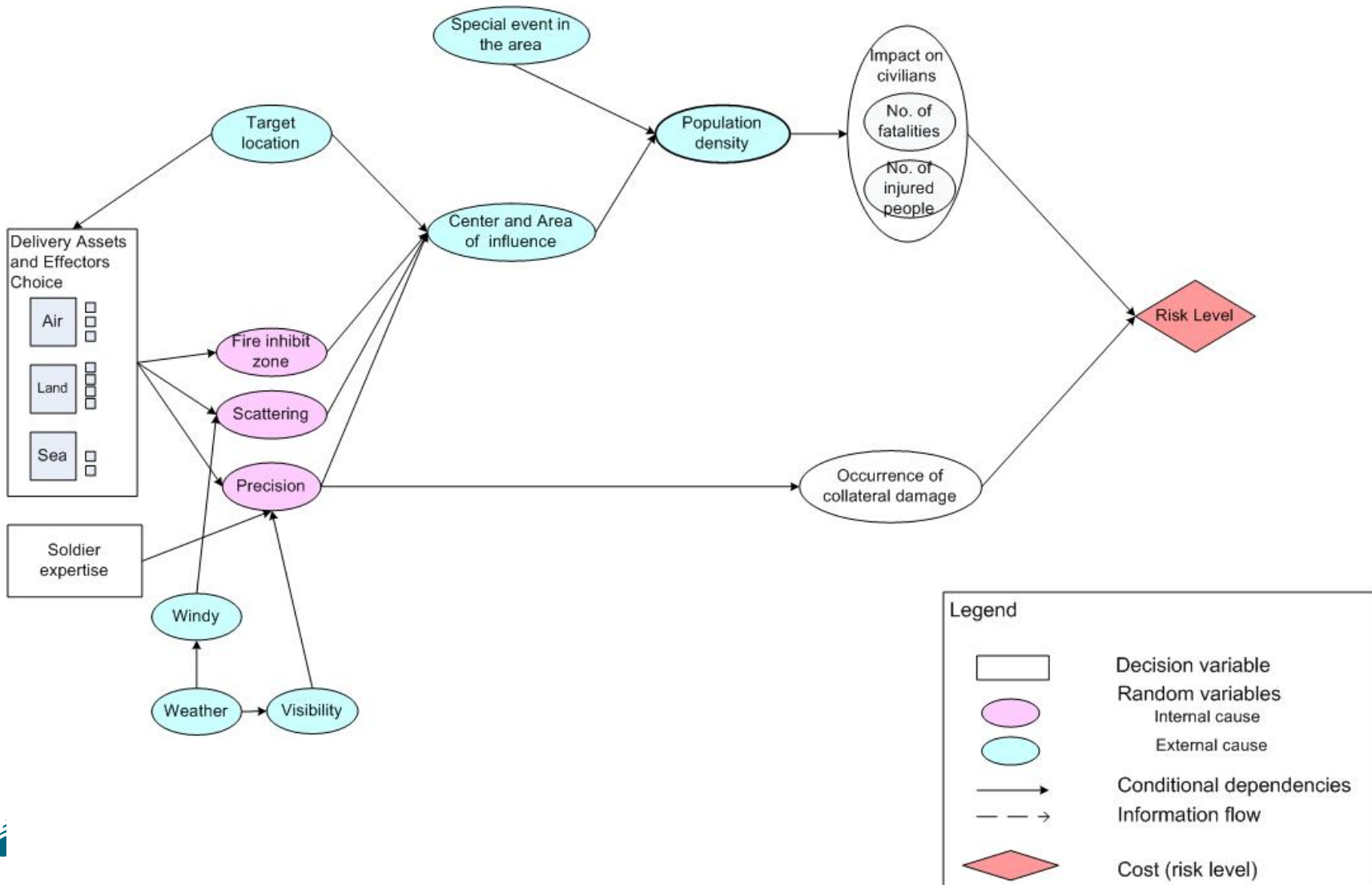
- **Personnel** (health and life)
- **Population** (health and life)
- **Mission** success
- **Resources** and equipment
- **Important buildings** (schools, hospitals)

# Risk assessment: Risk of collateral damage using Bayesian network



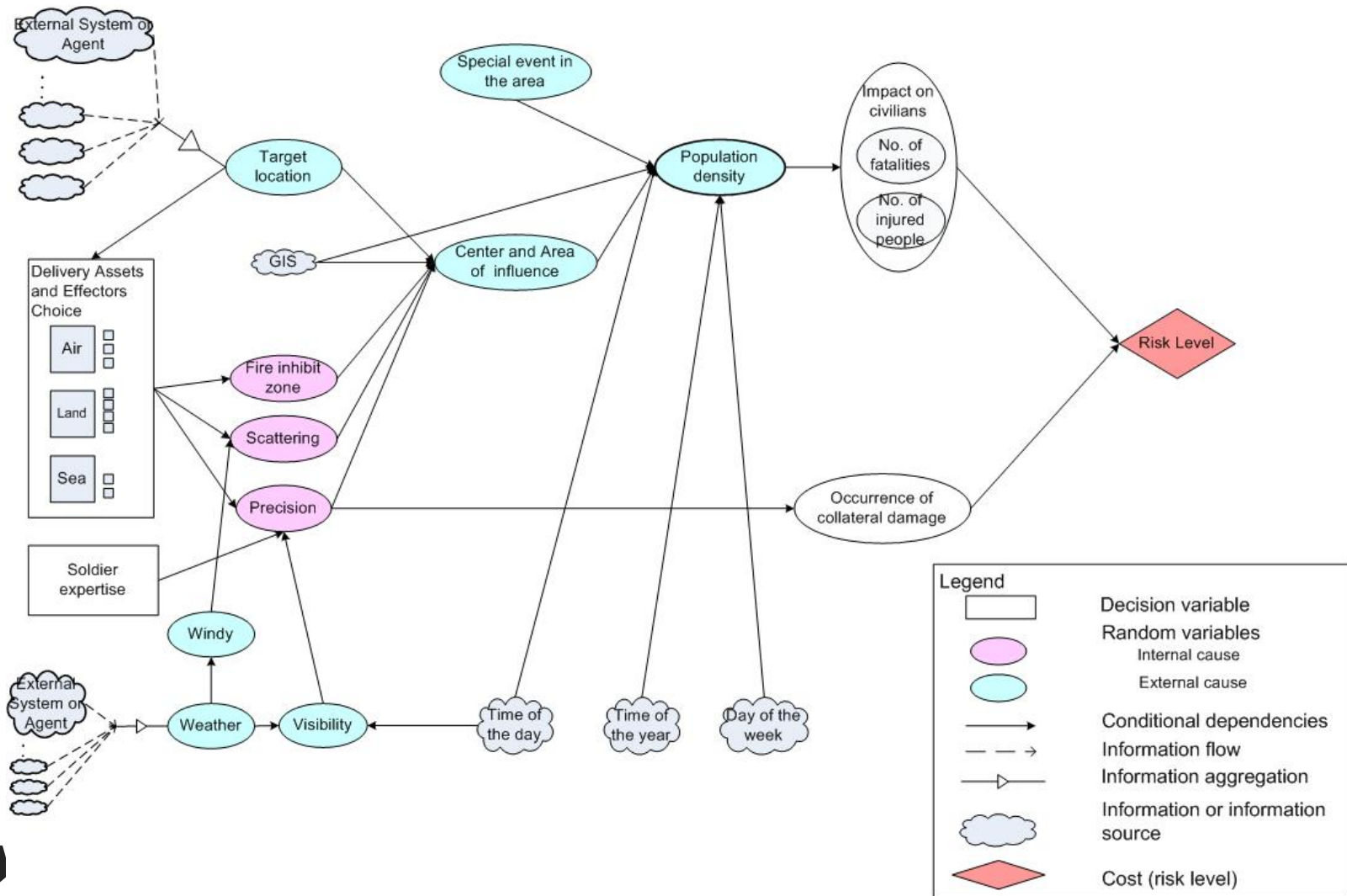


# Decision making and Risk assessment: Risk of collateral damage vs. choice of delivery assets using Influence diagram



# Aggregation of risk related information: Decision making and Risk assessment

## Risk of collateral damage vs. choice of delivery assets using Expanded Influence Diagram



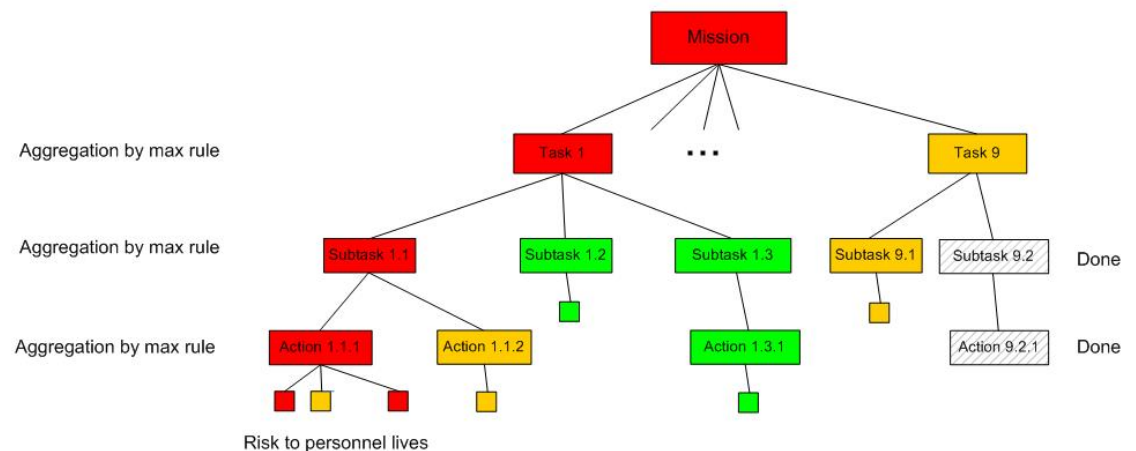
# Bottom-Up **Aggregation of Risks** along the Mission Decomposition Structure

Aggregation strategy depends on risk type:

- Max rule
- By importance
- Weighted sum

In each leaf node:

- (Expanded) Influence Diagram or
- (Expanded) Bayesian Network [Mission Decomposition Structure \(MDS\) and Risk to Personnel Lives](#)



# Mission Decomposition Structure (MDS) and Risk of Mission Failure

Aggregation by importance:

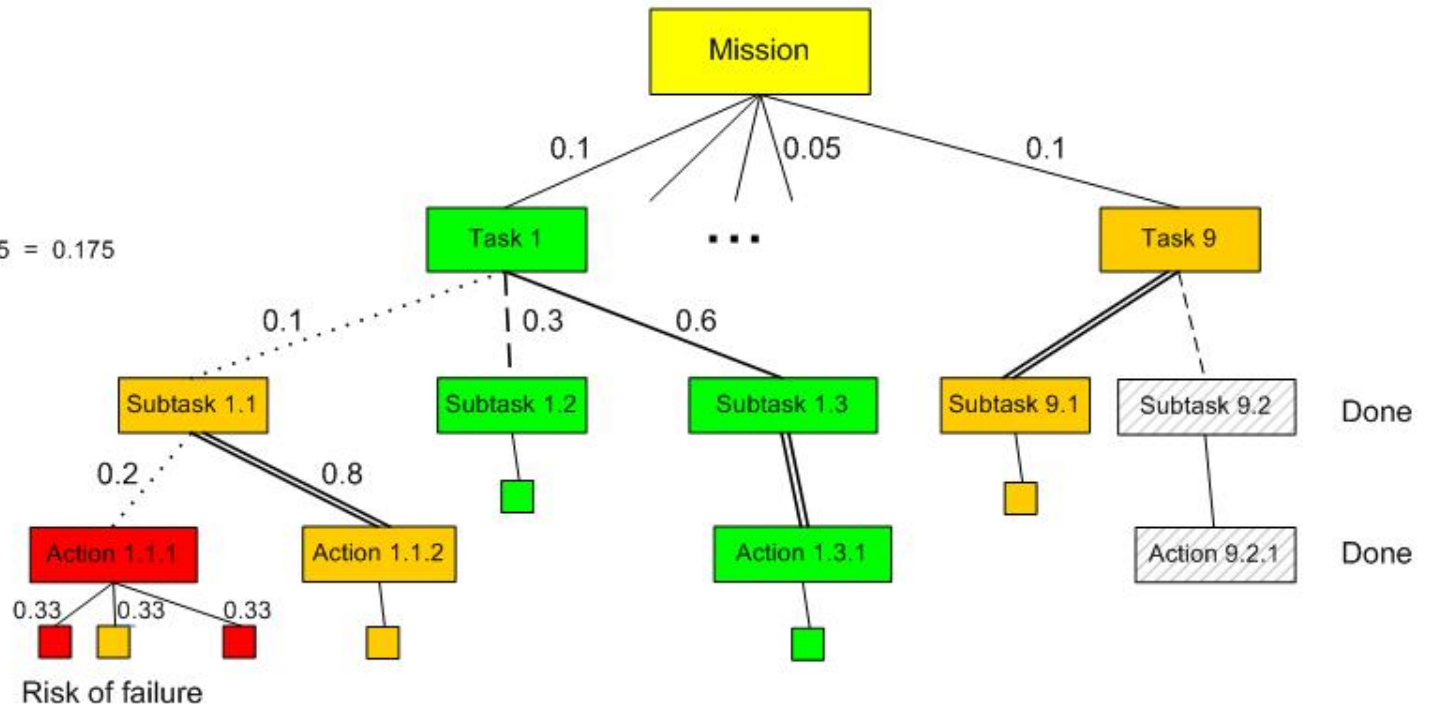
$$0.1 \times 0.625 + 0.3 \times 0.125 + 0.6 \times 0.125 = 0.175$$

Aggregation by importance:

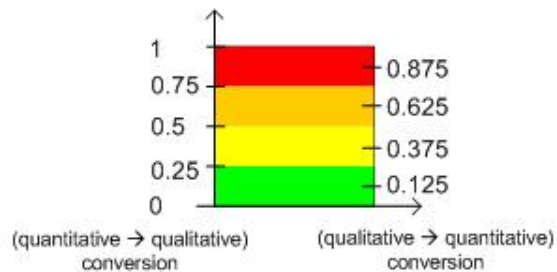
$$0.2 \times 0.875 + 0.8 \times 0.625 = 0.675$$

Aggregation by importance:

$$0.33 \times 0.875 + 0.33 \times 0.625 + 0.33 \times 0.875 = 0.784$$



Risk levels and (qualitative, quantitative) conversion rules



# Aggregation/Disaggregation of Risk

Aggregation of different risk types is usually not recommended

But if aggregation of different risk types is done, it has to be **transparent**

The screenshot shows the 'JFS - Joint Risk Management' application window. The main area is titled 'Assignments and Risks' and has several tabs: 'Mission', 'Personnel', 'Collateral', 'Buildings', 'Resources', and 'AGGREGATED'. The 'AGGREGATED' tab is selected. Below the tabs is an 'Assignment' section with a grid of risk types (D1-D7) across time periods (T1-T5). A red circle highlights the cell for D1 at T1. A legend below the grid shows color-coded boxes for 'Agg', 'M', 'P', 'C', 'R', and 'B'. To the right of the grid are buttons for 'Automatic', 'Manual', and 'Clear'. Below these are four solution options listed in a scrollable area: 'Solution 1 [a, 4]: 3 Y, 6 Y', 'Solution 2 [a, 5]: 3 O, 4 O', 'Solution 3 [m, 4]: 3 O, 5 O', and 'Solution 4 [m, 5]: 2 R, 3 R'. At the bottom of the solution list are 'Save', 'Delete', and 'Accept' buttons. Below the solution list is a 'Related Actions' section with a row of boxes labeled A0 through A8, each with a green or yellow background.

	T1	T2	T3	T4	T5
D1	Agg	M		R	
D2		M			
D3	M	P	M		
D4		P	R	R	M
D5		P	P	X	X
D6	X	P	X		
D7		P	M	M	M

Legend: Agg (Red), M (Yellow), P (Orange), C (Red), R (Yellow), B (Yellow)

Solutions:  
Solution 1 [a, 4]: 3 Y, 6 Y  
Solution 2 [a, 5]: 3 O, 4 O  
Solution 3 [m, 4]: 3 O, 5 O  
Solution 4 [m, 5]: 2 R, 3 R

# Decision-making support

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Assignment

	T1	T2	T3	T4	T5
D1	X	Yellow		Red	
D2					
D3	Yellow	Red			
D4		Red			
D5		Red			
D6	Yellow	Red	Green		
D7		Red	X	Yellow	Yellow

Mission Decomposition Structure Ctrl-M  
Dependency graph Ctrl-D

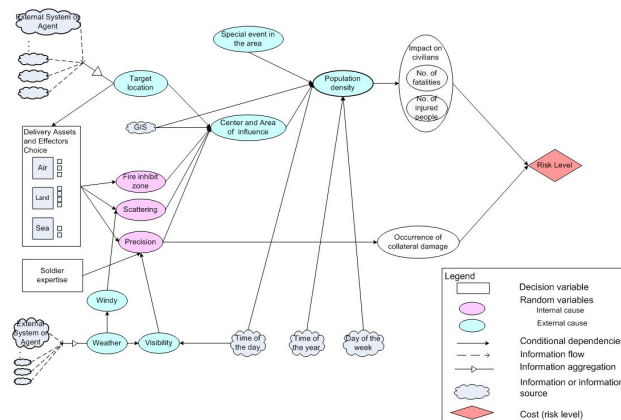
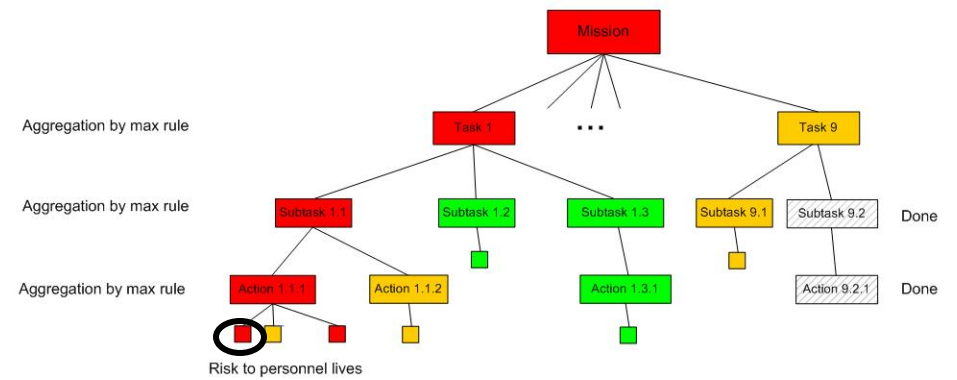
# Decision-making support

**Assignment**

	T1	T2	T3	T4	T5
D1	X				
D2					
D3					
D4					
D5					
D6					
D7					

**Mission Decomposition Structure** Ctrl-M  
**Dependency graph** Ctrl-D

## Mission Decomposition Structure (MDS) and Risk to Personnel Lives





Assignments and Risks

Mission Personnel Collateral Buildings Resources **AGGREGATED**

Assignment

	T1	T2	T3	T4	T5
D1	Red	Yellow	Grey	Red	Grey
D2	Grey	Yellow	Grey	Grey	Grey
D3	Yellow	Red	Yellow	Grey	Grey
D4	Grey	Red	Grey	Red	Yellow
D5	Grey	Red	Red	Yellow	Yellow
D6	Yellow	Red	Green	Grey	Grey
D7	Grey	Red	Yellow	Yellow	Yellow

Automatic Manual Clear

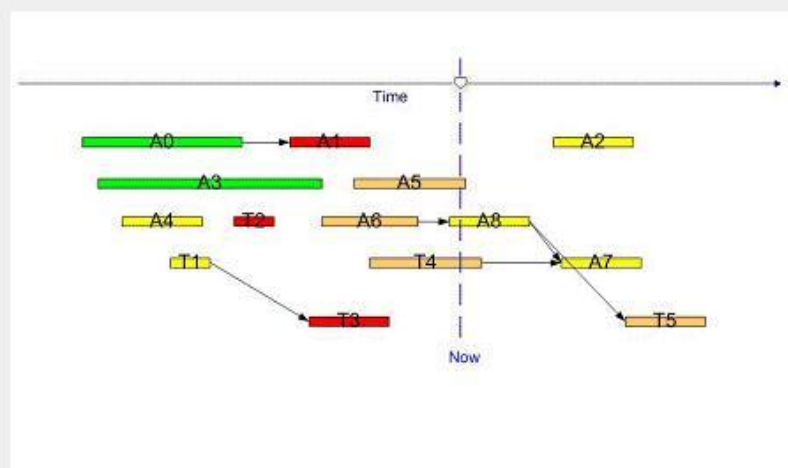
Solution 1 [a, 4]: 3 Y, 6 Y  
 Solution 2 [a, 5]: 3 O, 4 O  
 Solution 3 [m, 4]: 3 O, 5 O  
 Solution 4 [m, 5]: 2 R, 3 R

Save Delete **Accept**

Related Actions

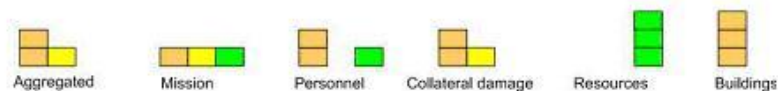
A0	A1	A2	A3	A4	A5	A6	A7	A8
Green	Red	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow

Gantt Chart

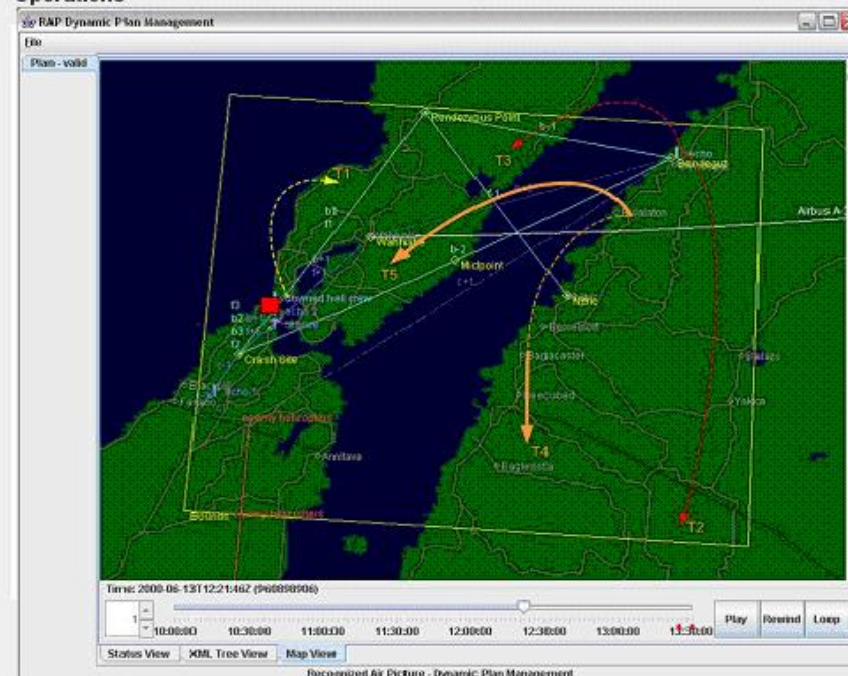


Simulation

Risks  Total  Only Assignments  Only Related Actions



Operations



All Assignments (Static) Play Pause Stop



# Real-time risk assessment and aggregation

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Do regularly (iteratively or triggered by events):

(D1) For each risk, assess its level, using EID;

(D2) For each risk type, aggregate risks over tasks, going upwards along the MDS, and

(D3) If needed, at each level of command and MDS, aggregate different risk types.

# Conclusion (1/2)

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- Proposed **Aggregation**/disaggregation methodology **includes**:
  - Aggregation of risk related information from different sources: **Expanded Bayesian network** (by using Dempster-Shafer theory of evidence)
  - Aggregation of decision making and risk related information from different sources: **Expanded Influence Diagram** (by using Dempster-Shafer theory of evidence)
  - Risk aggregation through command structure: **Mission Decomposition Structure** and **different risk aggregation strategies** for **different risk types**
  - Each **leaf** of the Mission Decomposition Structure has corresponding influence diagrams

## Conclusion (2/2)

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Presented methodologies **support:**

- Risk aggregation and disaggregation
- Comprehensive view for easier decision making
- Real-time monitoring of causes, risks, and controls
- Proper communication and visualization of risk related data
- Risk management at different levels of command structure
- Collaboration in joint multi-agency operations

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Questions?

