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All For The Want of a Horseshoe Nail
An Examination of Causality in DoDAF and MODAF

Matthew Hause – Atego, Lars-Olof Kihlström – Syntell AB

Agenda

- Causality
- The IDEAS Foundation
- Modeling Causality
- Modeling in UPDM
- Simulation
- Additional Concepts
- Conclusion

The Battle of Bosworth

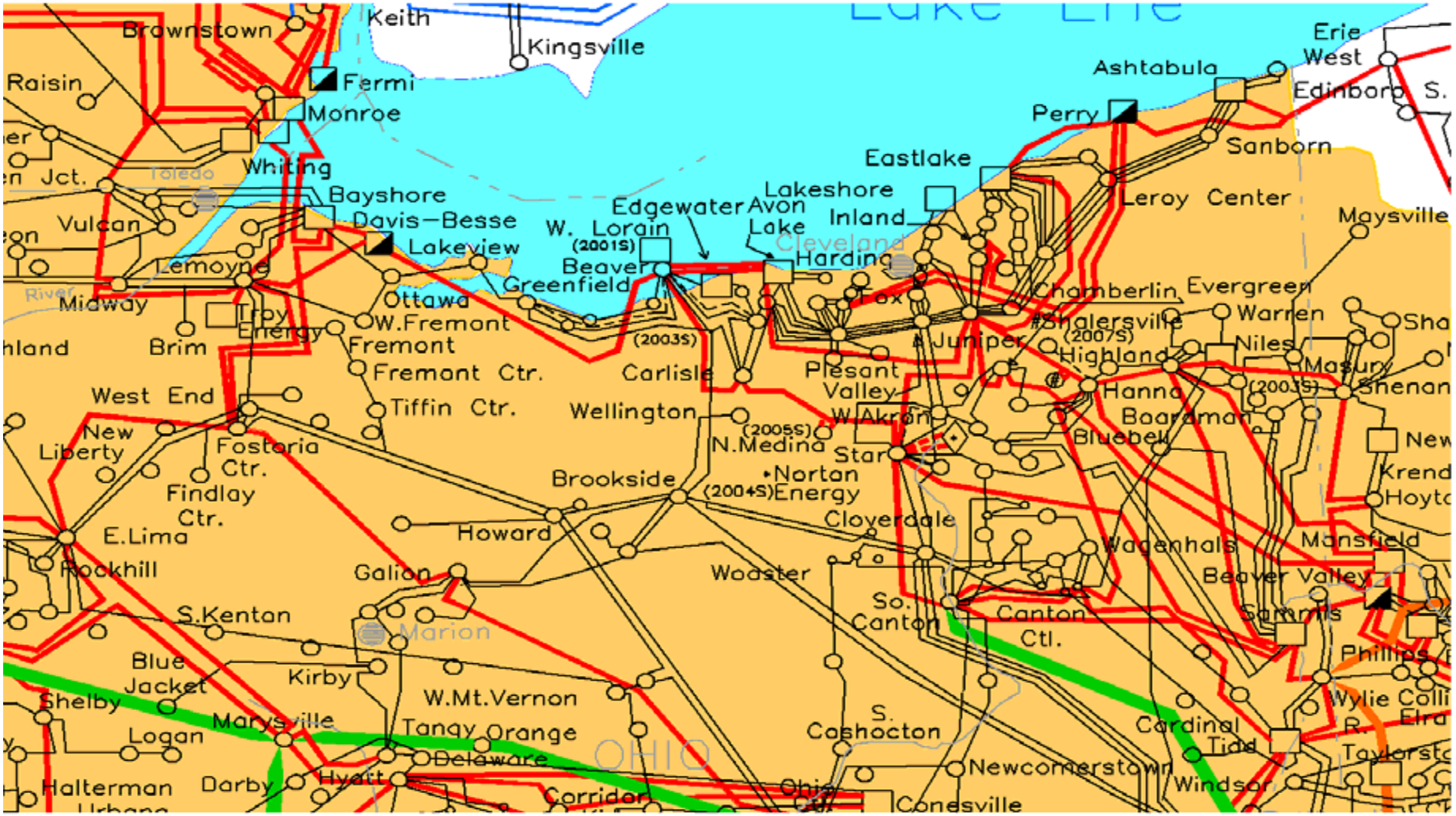
- For want of a nail the shoe was lost.
  For want of a shoe the horse was lost.
  For want of a horse the rider was lost.
  For want of a rider the message was lost.
  For want of a message the battle was lost.
  For want of a battle the kingdom was lost.
  And all for the want of a horseshoe nail.

- Refers to the death of Richard III of England.
- A simple event kicks off a causal sequence resulting in catastrophic consequences (if you were a Plantagenet)

Causality

- "Causality (also referred to as causation) is the relation between an event (the cause) and a second event (the effect), where the second event is understood as a consequence of the first."
  Random House Unabridged Dictionary
- Causes and their effects are typically related to changes or events. Also caused by objects, processes, properties, variables, facts, and states changes, etc.
  - These concepts can be modeled in DoDAF/MODEM
- Characterizing the causal relation can be difficult.
  - Correlation is not causation
  - I.E. Sacrificing an animal to the gods does not cause a good harvest.

Northeast USA and Canada Electric Blackout 2003



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Investigating a Historical Chain of Events

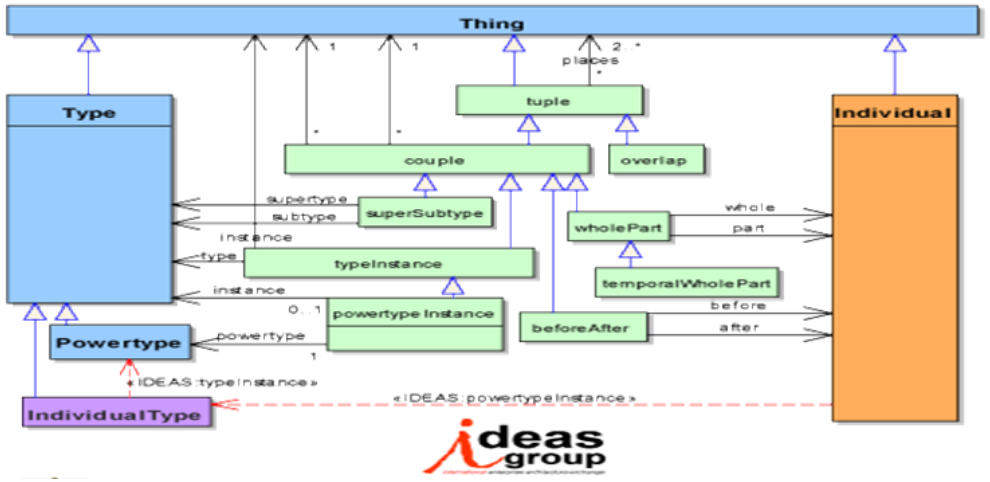
- What was the causal sequence?
  - Abnormally hot weather increased A/C load causing
    Power load to increase causing
    Power lines to sag and contact trees causing
    Line faults causing
    Electrical outages causing a massive outage
- What circumstances enabled this sequence?
  - The trees were taller than they should have been because the power company cut the tree trimming budget to save money to remain competitive because of deregulation caused by a change in the political environment caused by…. (You get the idea.)
  - Human factors were also directly involved because the operators had sufficient advanced warning of the problem but ignored the warning messages.
  - Sensors measuring power flow were faulty.
  - Other causes were also documented
- Well documented and understood due to extensive data logging

Causality as such

- Semantically, causality is a fairly tricky subject.
- There is causality that is due to the laws of physics: If a stone is dropped from a height, gravity will **cause** the stone to fall to the ground below.
- There is causality that is due to a law prescribed by society: If I park my car in a no-parking zone, the **cause** of me getting a parking ticket was that I broke a law regarding car-parking (and that I was unlucky enough to get caught doing it).
- There is causality where someone has determined that something caused something to happen: The black-out was **caused** by budget cuts concerning tree-trimming, warning messages being ignored and faulty sensors.
- The last was an after-the-fact determination but brings up another issue namely results that are **desired** by someone or intended results when making use of something or in other words **effects**.
- Can causality be modelled?

IDEAS - Top-Level Foundation

- Developed by an international group of computer scientists, engineers, mathematicians, and ontologists under defense sponsorship.
- See http://www.ideasgroup.org or http://en.wikipedia.org/wiki/IDEAS_Group



- http://dodcio.defense.gov/Home/Topics/EnterpriseArchitectureStandards.aspx
- https://www.gov.uk/mod-architecture-framework
- UPDM 2.1 and UPDM 3.0 (OMG finalized standard as well as ongoing standards work)
- Candidate for next version of NATO architecture framework (NAF version 4).

Let us look at this from the point of view of a scenario

- In a country currently in the midst of severe internal strife a number of foreign nationals are kidnapped and held hostage at two different locations in an urban area.
  - The country whose nationals had been kidnapped had previously experienced kidnapping and had therefore decided that specially trained and equipped military personnel would be required that will be able to deal with hostage rescue provided intelligence as to the whereabouts of the hostages is available.
  - The main goal of the hostage citizen country is to rescue kidnapped nationals with as little collateral damage as possible and to send a message to would-be kidnappers that kidnapping persons from this country does not pay.
  - The rescue should ideally also result in positive overall recognition in the international arena.

Let us look at this from the point of view of a scenario

- In this case intelligence of the whereabouts turned up and two teams were dispatched to attempt to deal with the hostage situation.
  - The first team were successful and the kidnappers were apprehended and the hostage rescued.
  - The second team ran into problems after the hostages had been secured and ended up in a fire fight with a much larger enemy unit than known to be present at the location.
  - After using demolition charges they were however able to get clear of the building they were in and get themselves to safety and the hostages to safety, with several of the rescue team injured however and one of the hostages severely wounded.

Let us look at this from the point of view of a scenario

- Unfortunately, the demolition charges weakened the structure of the building, causing the building to collapse two days later killing a number of totally innocent civilians in the process.
- The kidnappers from one location were apprehended and brought to justice and this initially resulted in positive international reactions.
- The second rescue handling was classified and only leaked out after a while and the international reaction after journalists were able to link the rescue attempt to the collapsed building was much less positive.

The scenario from an effect perspective

- **Scenario:**
- *Capability:*
  - Hostage rescue ability
- *Effect that implementations of the capability are intended to achieve:*
  - Hostages safely rescued uninjured
- *Implemented capability:*
  - Specially trained and equipped military hostage rescue team
- *Desired effect by desirer:*
  - Hostages safely rescued desired by country of the kidnapped citizens,
  - Warning to would be kidnappers (same desirer),
  - Favourable international reactions to rescue (same desirer).

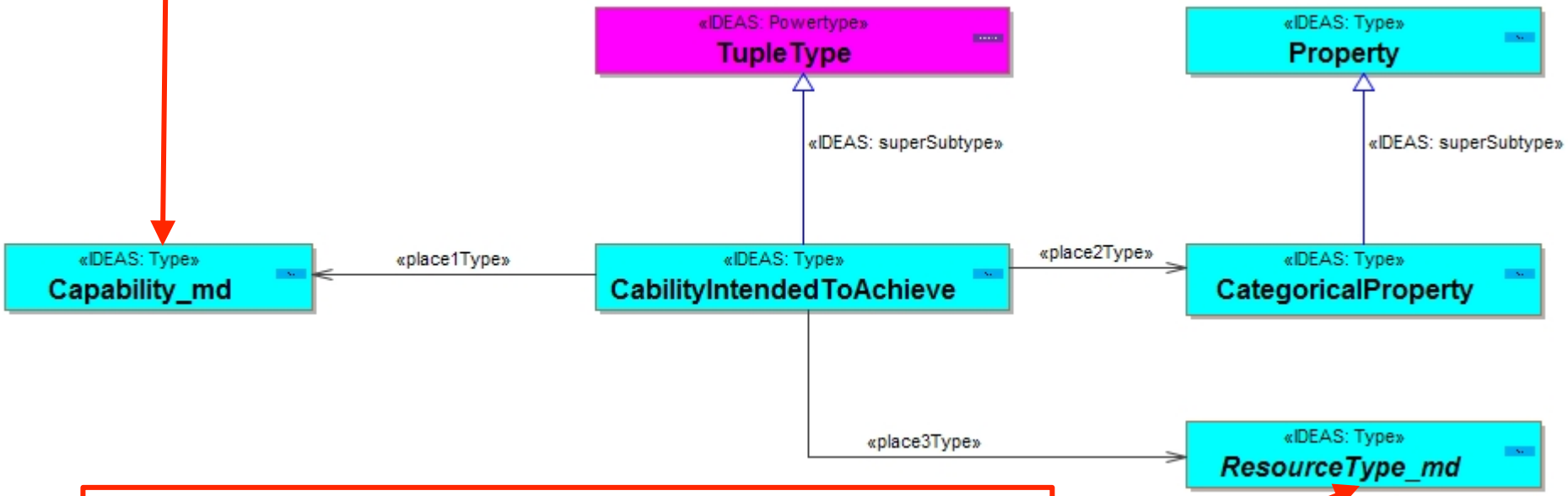
The scenario from an effect perspective

- *Actually achieved effects on what:*

- Hostage group 1 safely rescued and kidnappers apprehended,
- Not clear whether this will act as a warning to would-be kidnappers,
- Hostage group 2 rescued with injuries both to team and hostages,
- Building stability compromised by demolition charge,
- Building collapse and collateral damage,
- Adverse international reaction to withheld cause of building collapse and collateral damage.

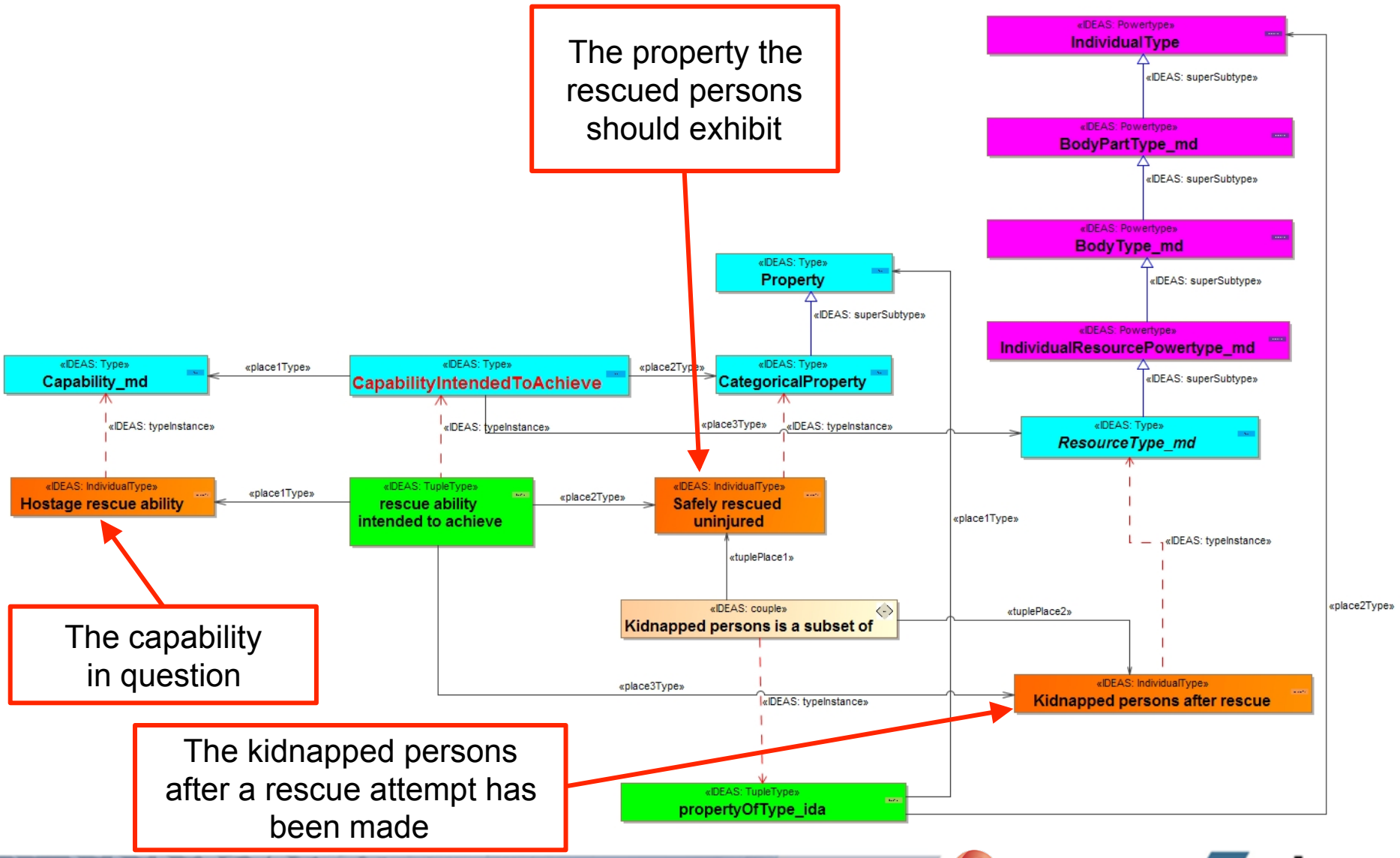
Intended effect/ result

A high level specification of the enterprise's ability.
Note: A capability is specified independently of how it is implemented.
Note: Capabilities are dispositional. A given system or organization that has a capability (i.e. it is disposed to do something) may never actually have manifested it.



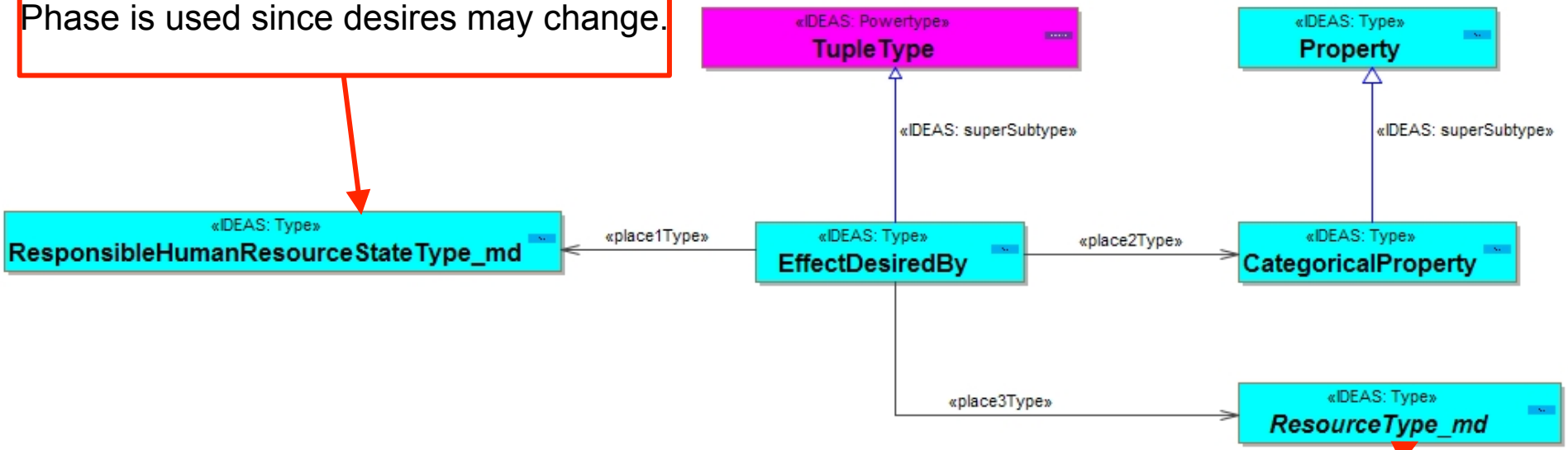
A combination of resources that implements the given capability where use of this resource Combination should result in a different resource configuration exhibiting a certain categorical property.

Intended scenario effect



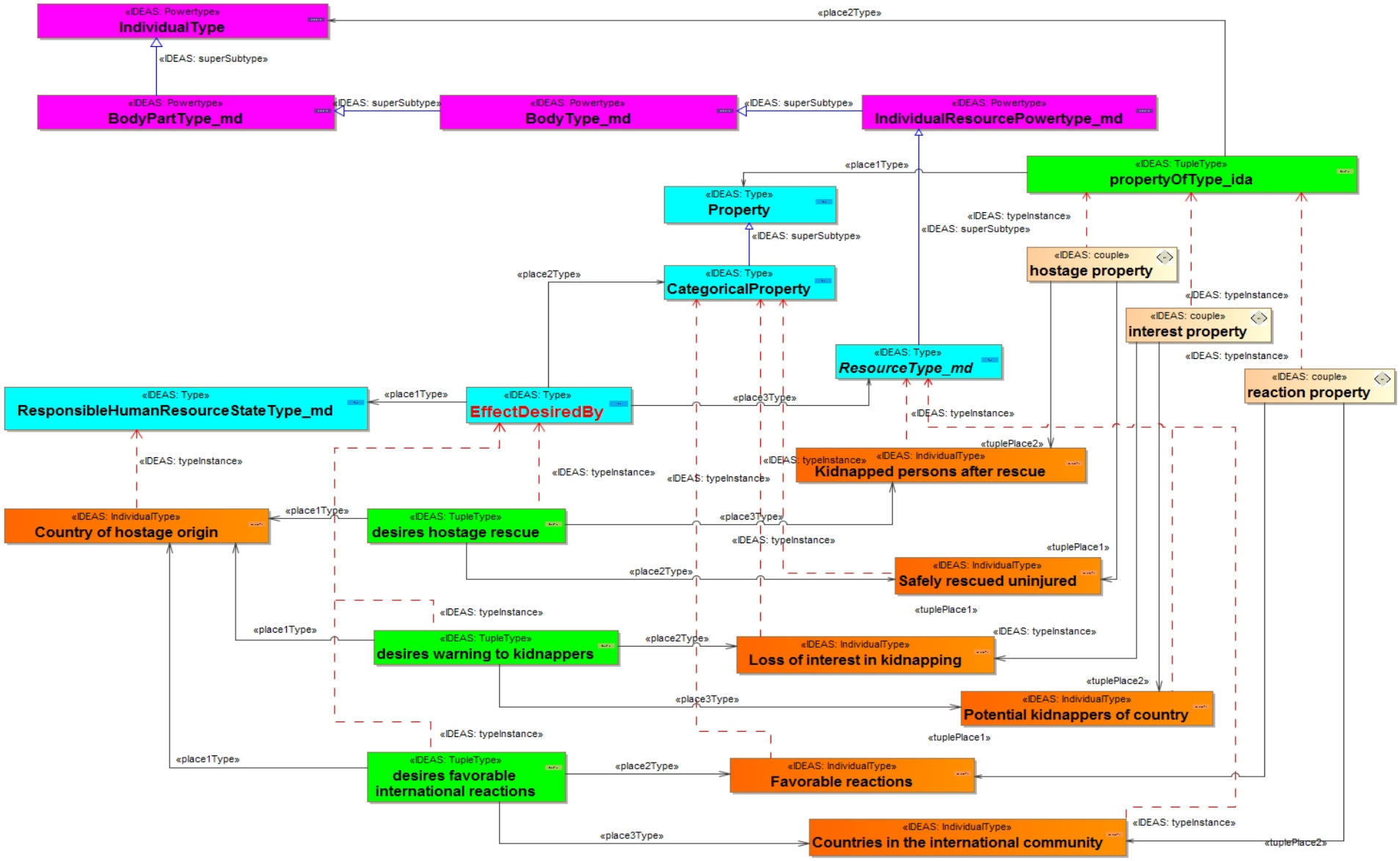
Desired effect/ result summary

The phase of some responsible human resource that desires to have an effect on a given resource. A temporal Phase is used since desires may change.

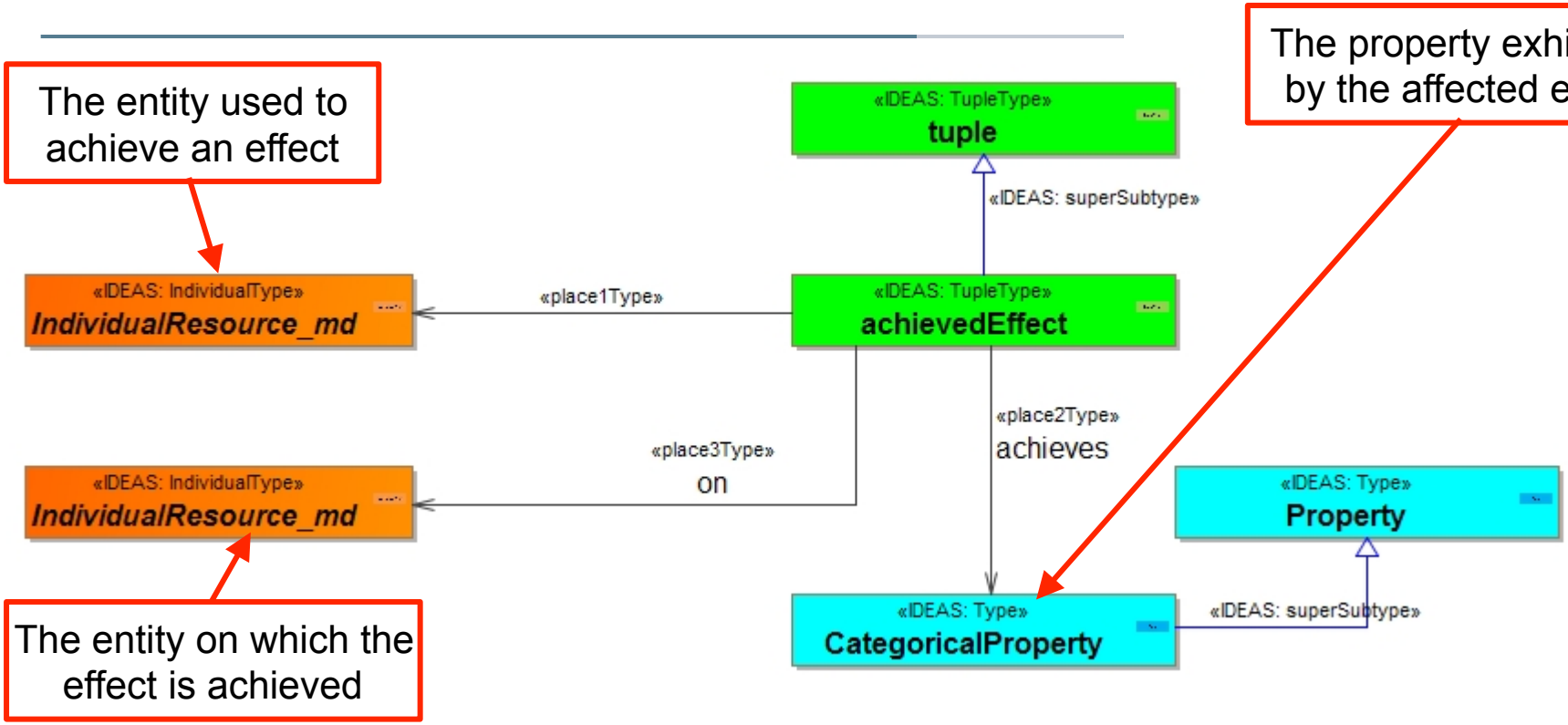


A combination of resources where there is a desire to have it exhibit a certain categorical property

Desired scenario effect

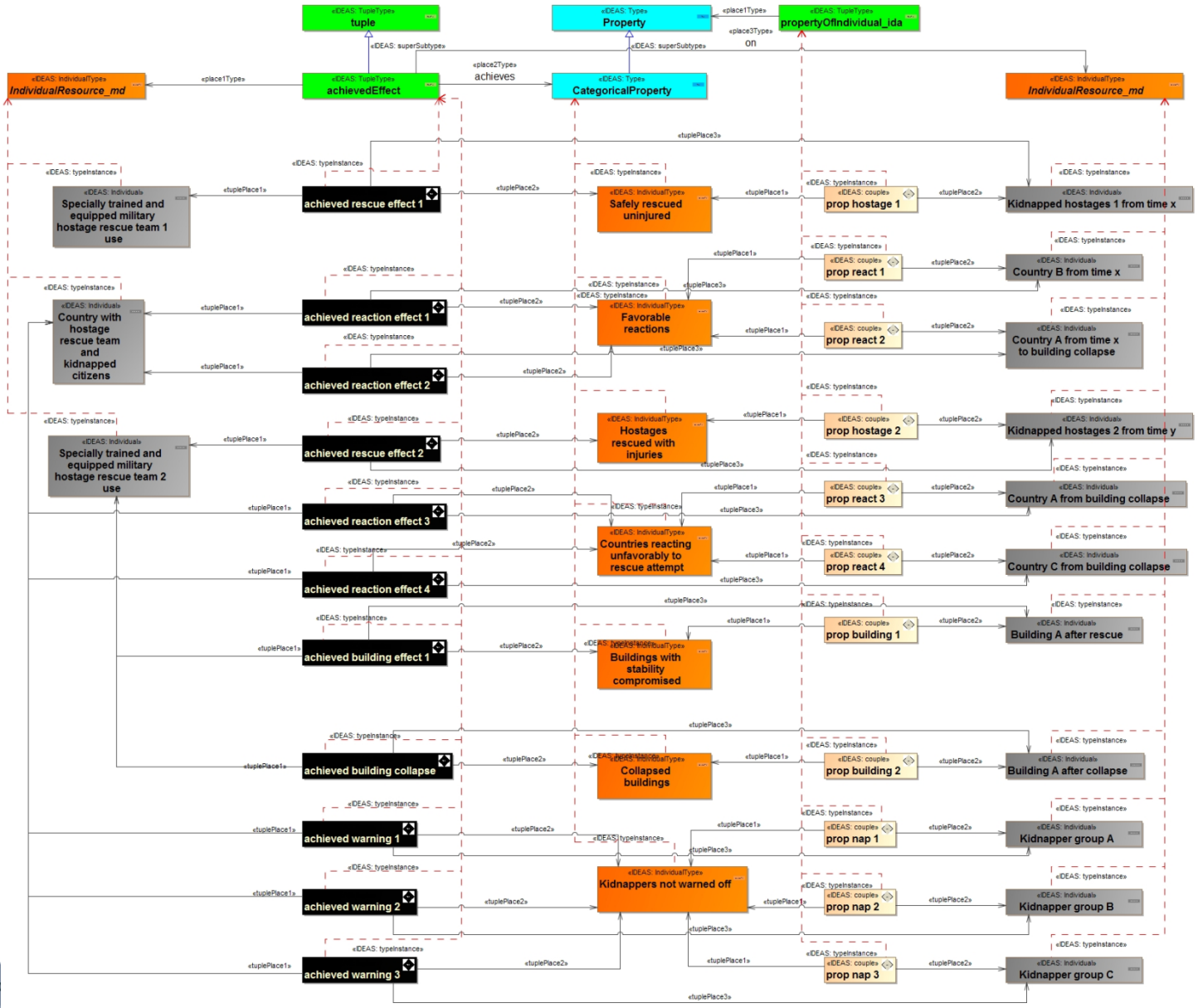


Achieved result/ effect summary model



- This can be summarized as described above by stating that the use of some configuration of resources on some other configuration of resources causes the latter to exhibit a specific property.
- Property can be subdivided into dispositional property as well as categorical property, the former implying that the configuration is able to exhibit this property but is not actually doing this at this point. The latter implies that the time slice of the configuration where it actually achieves this property is implied.

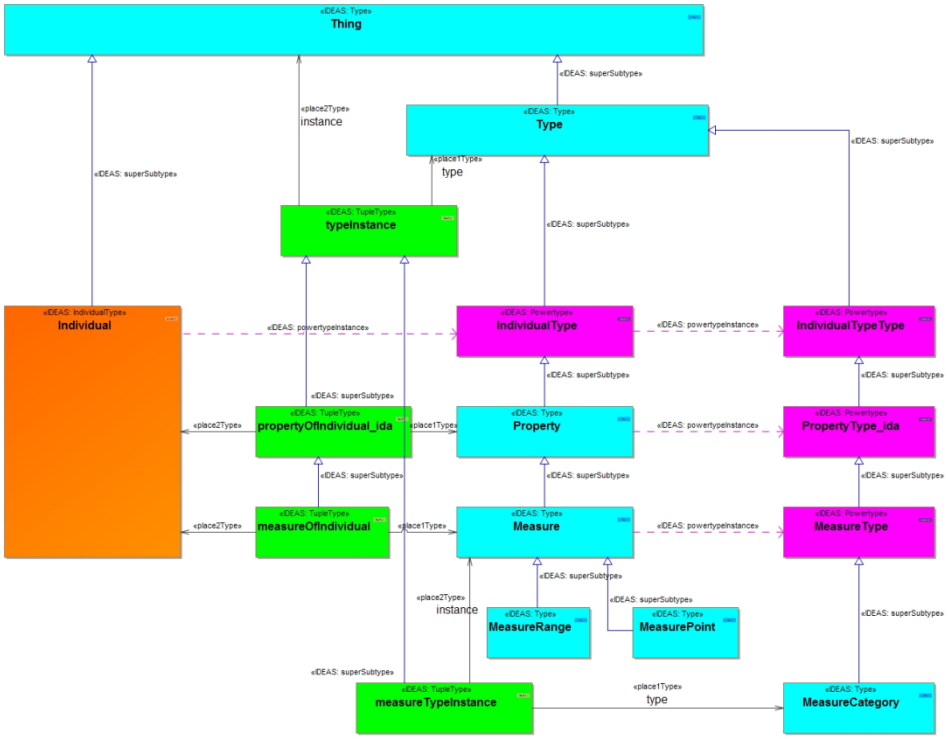
Achieved effect: hostage scenario

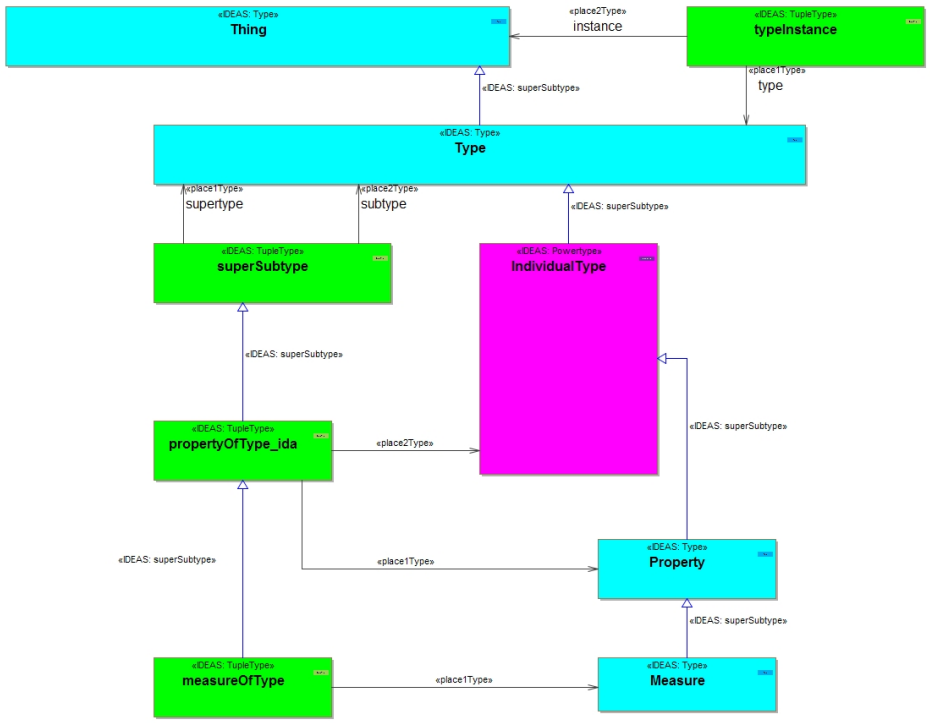


A possible addition

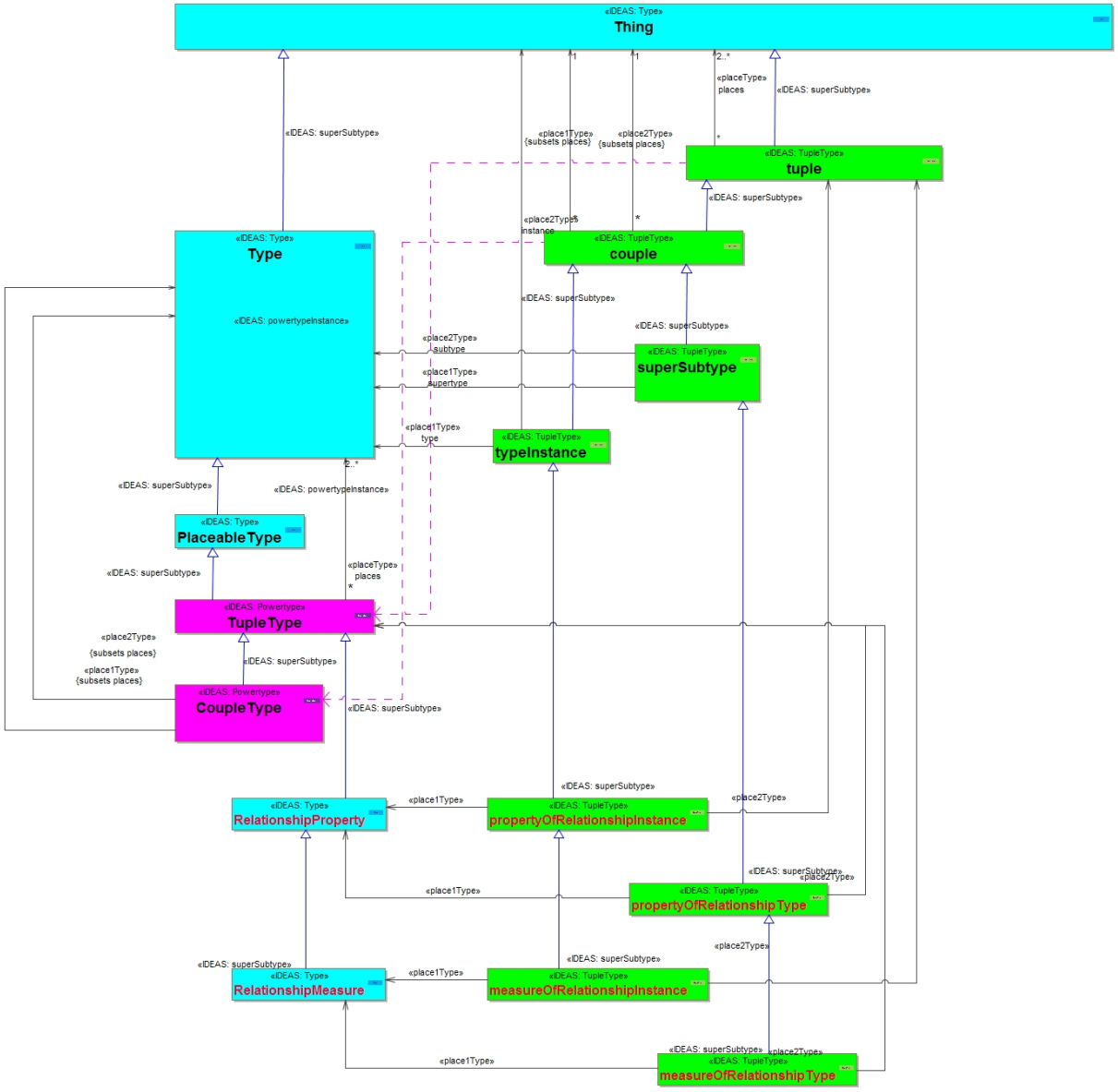
- Since the achieved effects part discusses what was actually accomplished, there is no interest in adding any kind of metric to these relationships.
- There may however well be an interest to consider metrics when dealing with the effect/ result intended to be achieved by a capability or when dealing with an effect desired by someone.
- This requires a bit of thought however since metrics within the IDEAS foundation and therefore also in MODEM as well as in DM2 can solely be associated with non relationships elements.
- The problem with the current metrics definition is outlined in the next slide and the slide after that presents a possible solution.

The issue with metrics and relationships





A possible approach



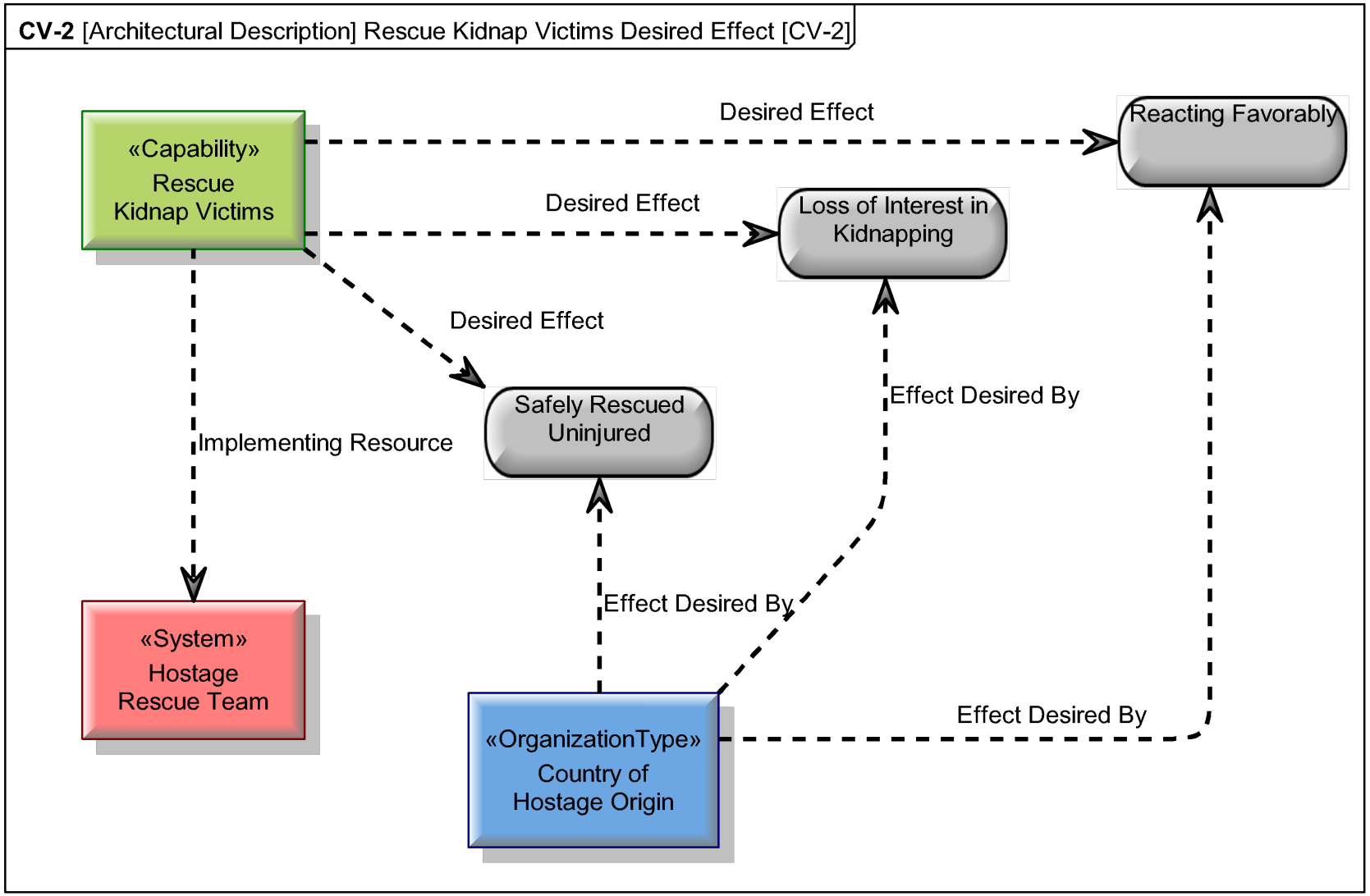
The Unified Profile for DoDAF and MODAF (UPDM)

- UPDM is a standardized way of expressing DoDAF and MODAF artefacts using UML and SysML
  - UPDM is *NOT* a new Architectural Framework
  - UPDM is not a methodology or a process
  - UPDM implements DoDAF 2.0, MODAF & NAF
- UPDM was developed by members of the OMG with help from industry and government domain experts.
- UPDM is a DoD mandated standard and has been implemented by multiple tool vendors.

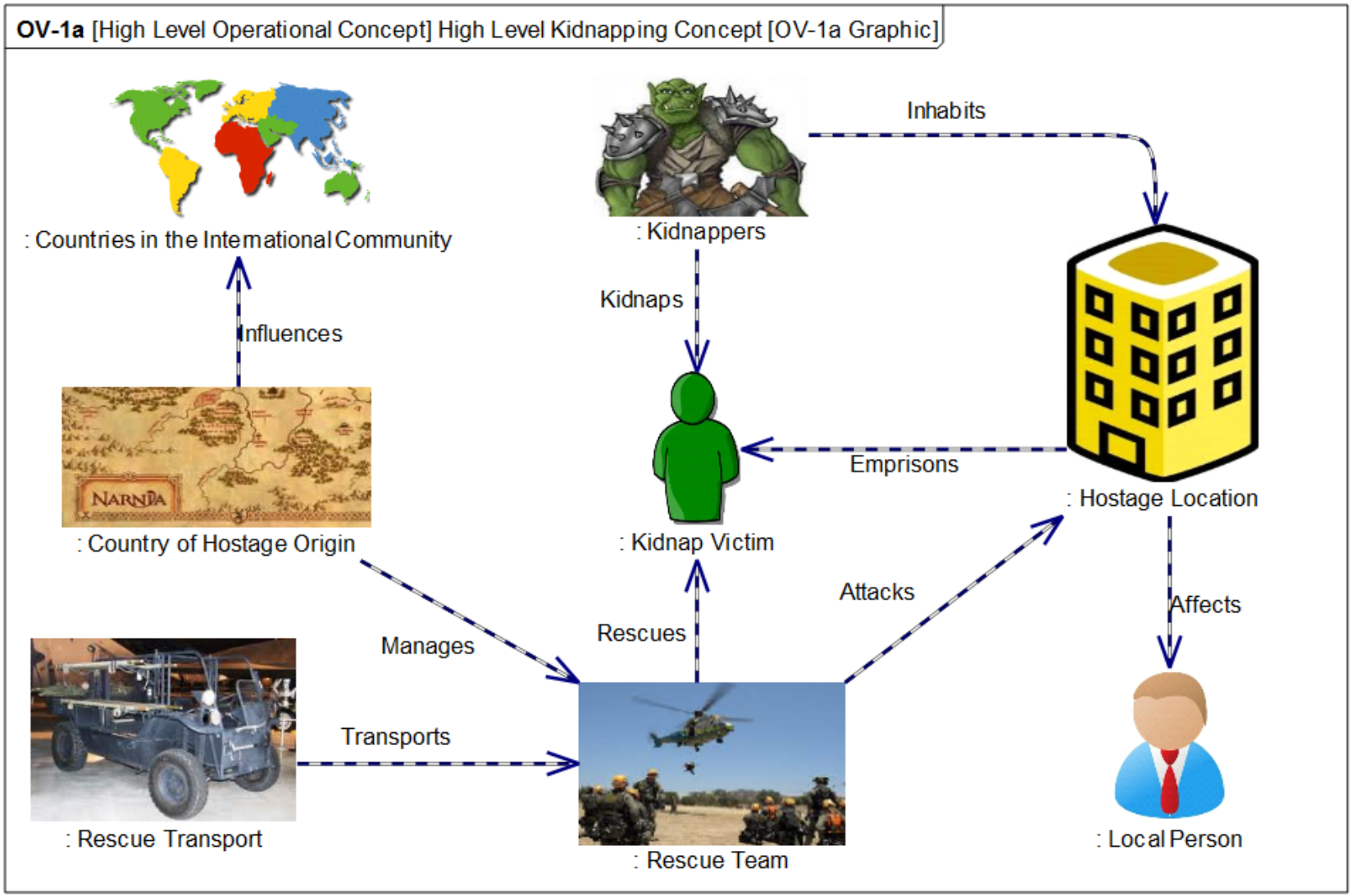
Representation in UPDM / SysML

- MODEM/DoDAF does not prescribe a graphical representation
  - Implementations such as UPDM are required for visualization
- State Diagrams
  - Models the state-based behavior of structural elements
  - Useful for capturing event/effect sequences
- Activity Diagrams
  - Used to model behavioral sequences using activities
  - Shows the flow of control and information
  - Can include structural elements
- Sequence Diagrams
  - Captures a series of interactions between structural elements
  - Can include timing information, parallel and optional sequences,
- SysML Parametric Diagrams
  - Captures the relationship between quantitative structural aspects

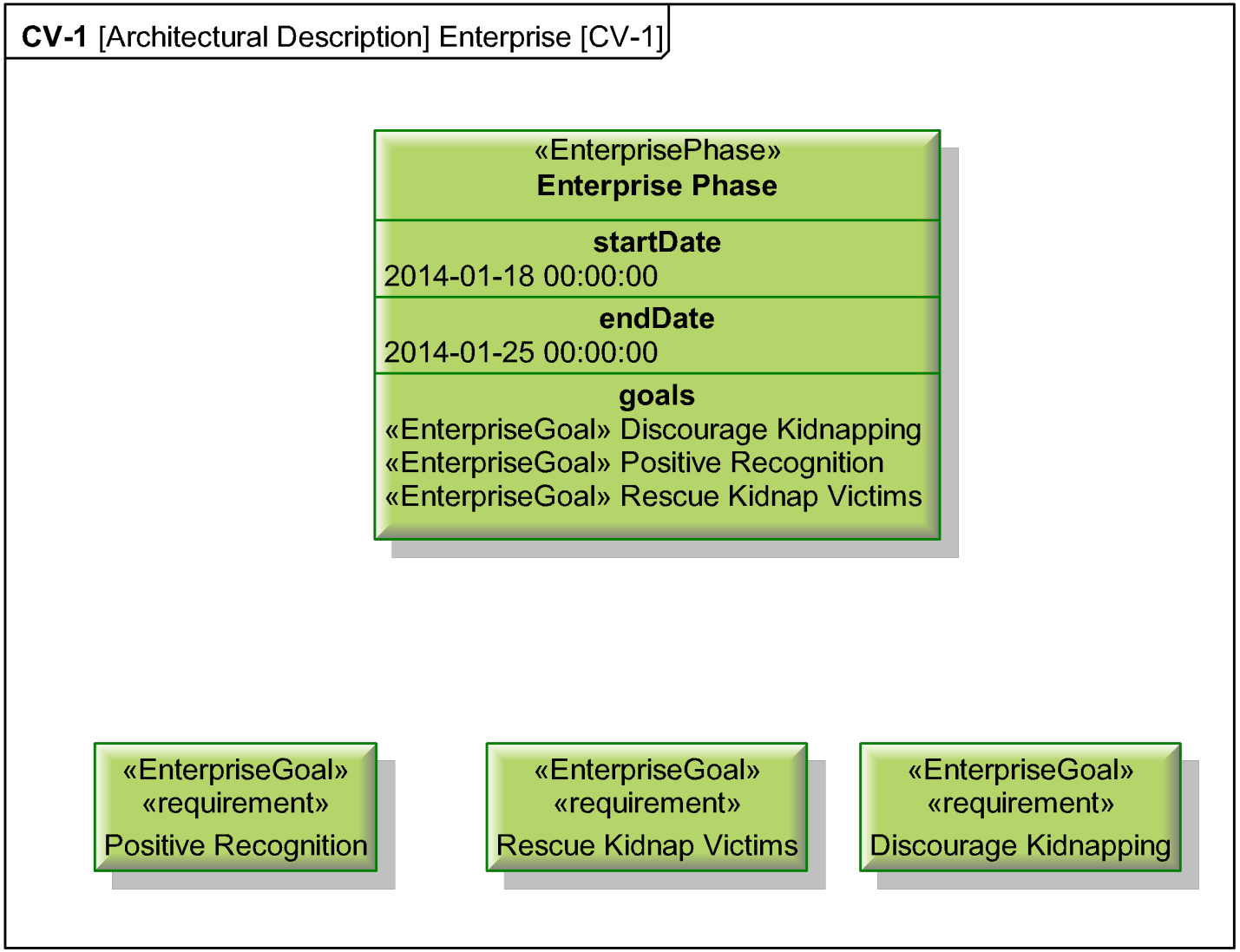
Capability Desired Effect



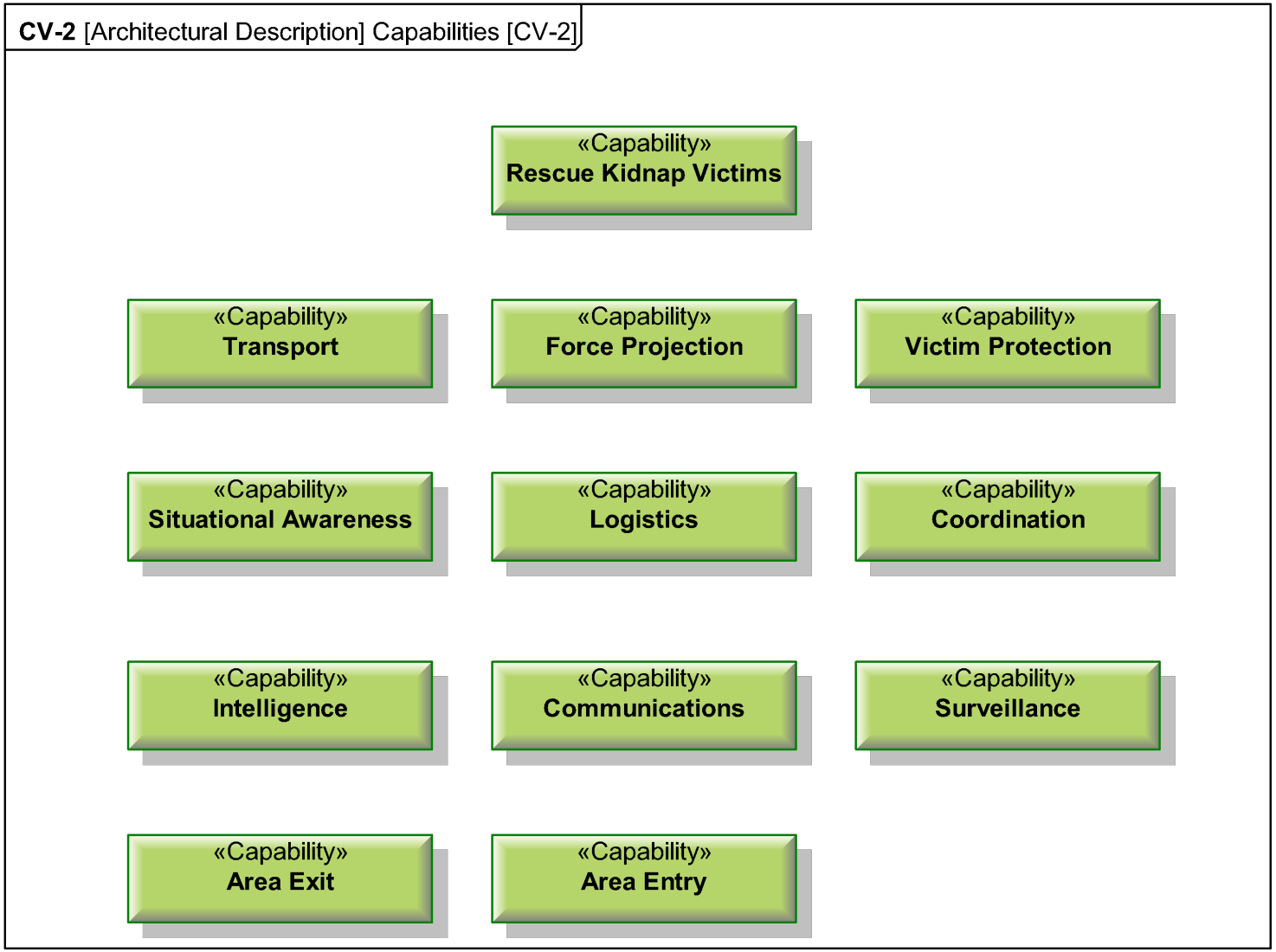
Kidnap Operational Concept



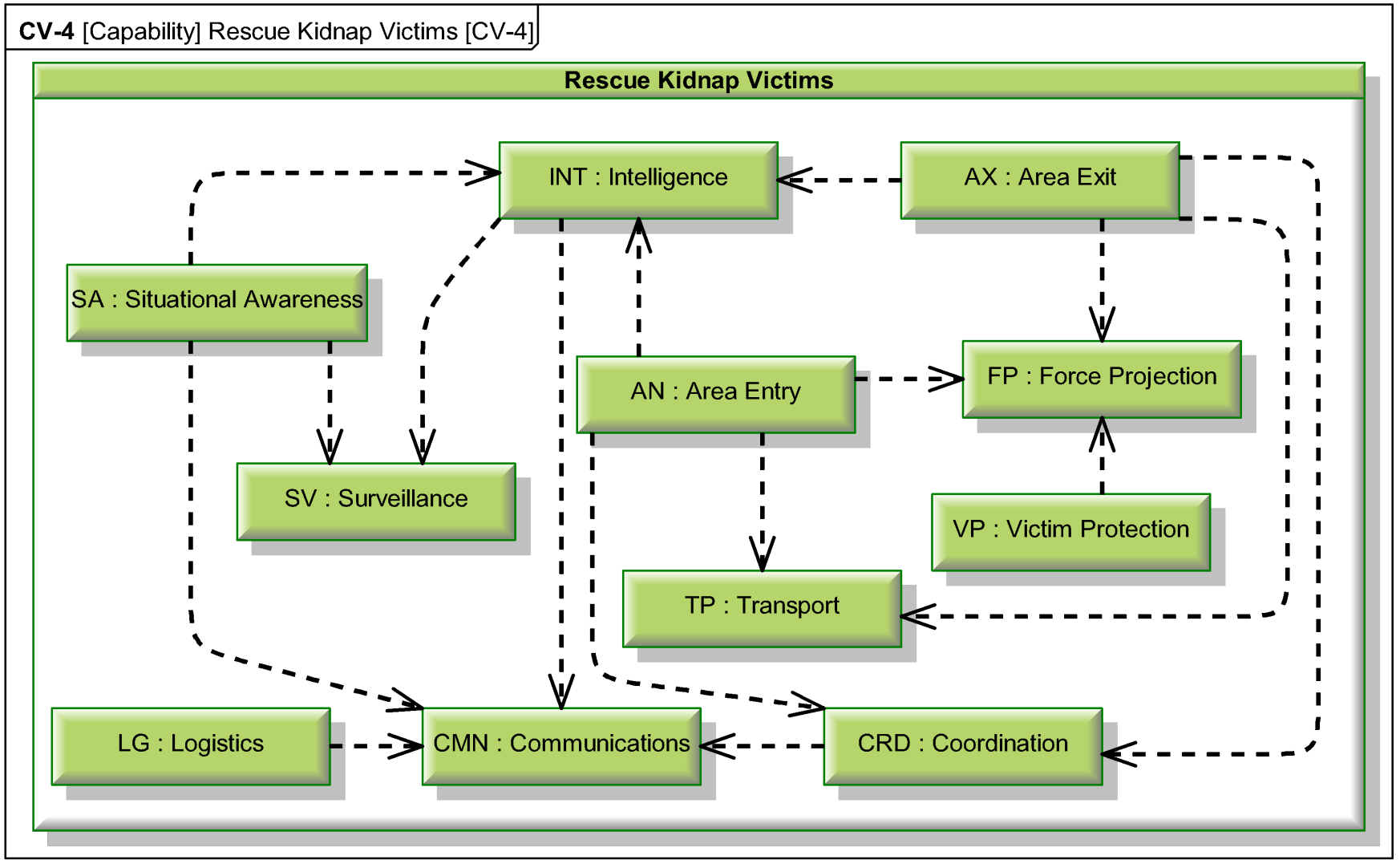
Enterprise Goals



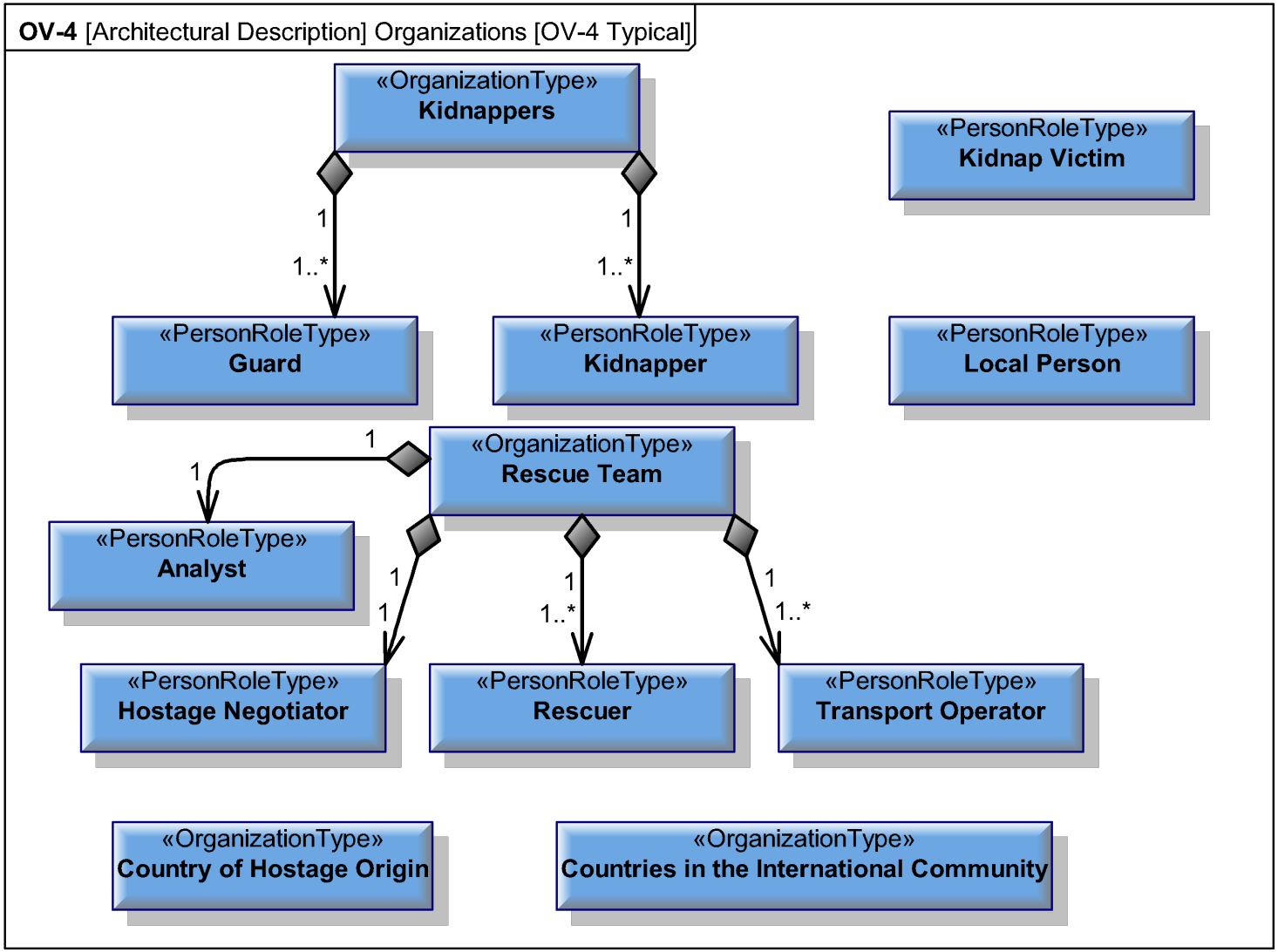
Kidnap Capability Taxonomy



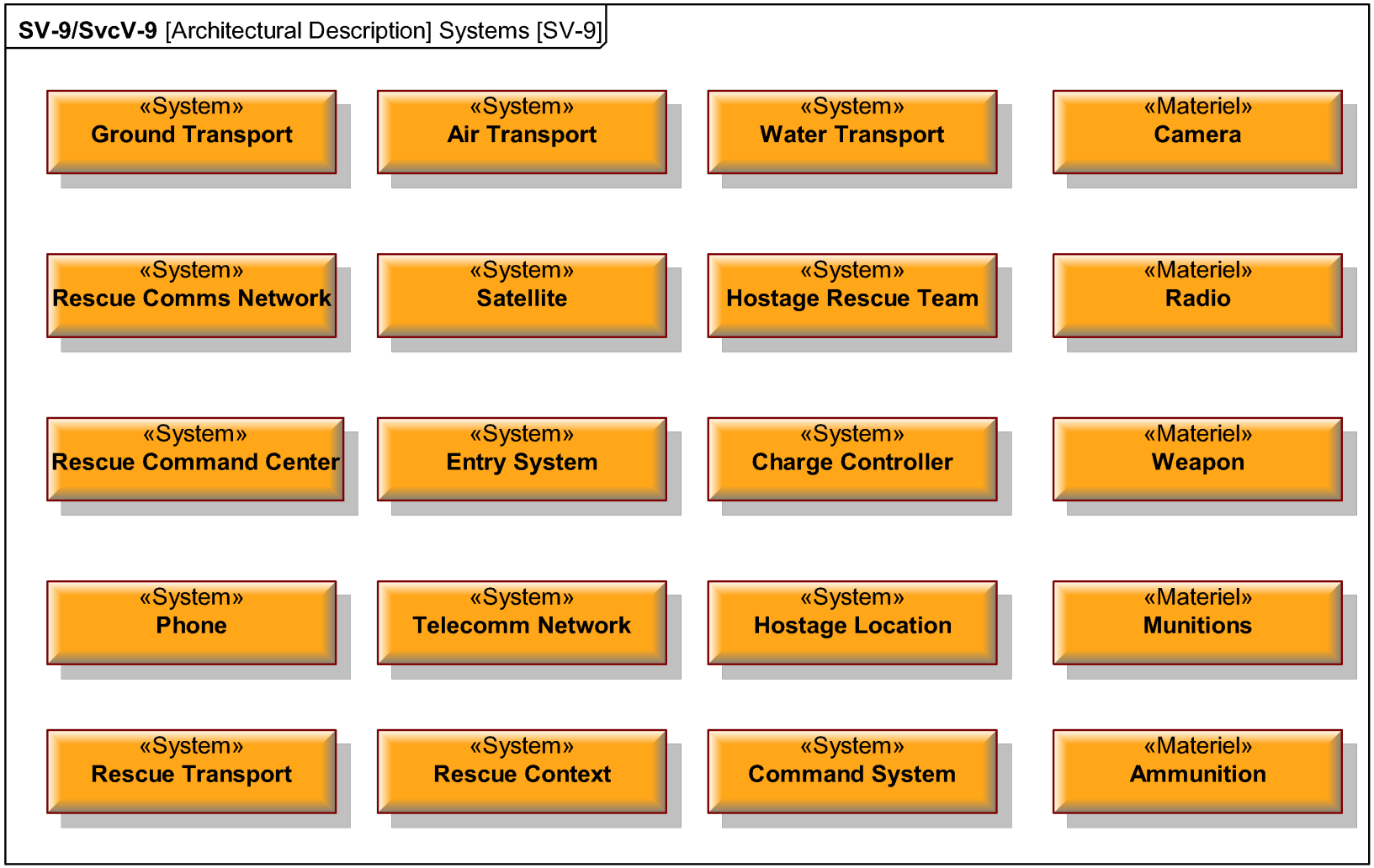
Kidnap Rescue Capability Dependencies



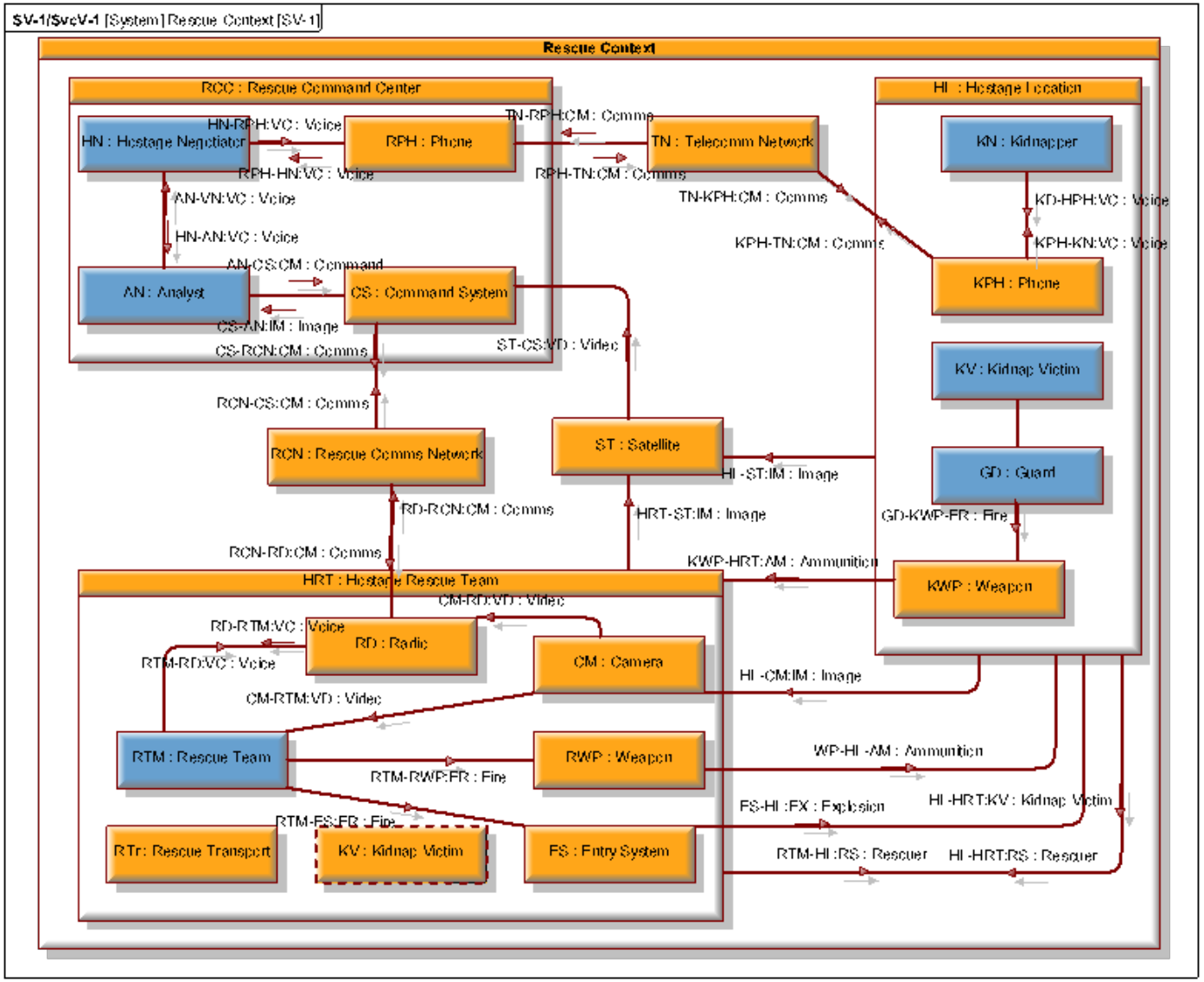
Kidnap Context Organizations



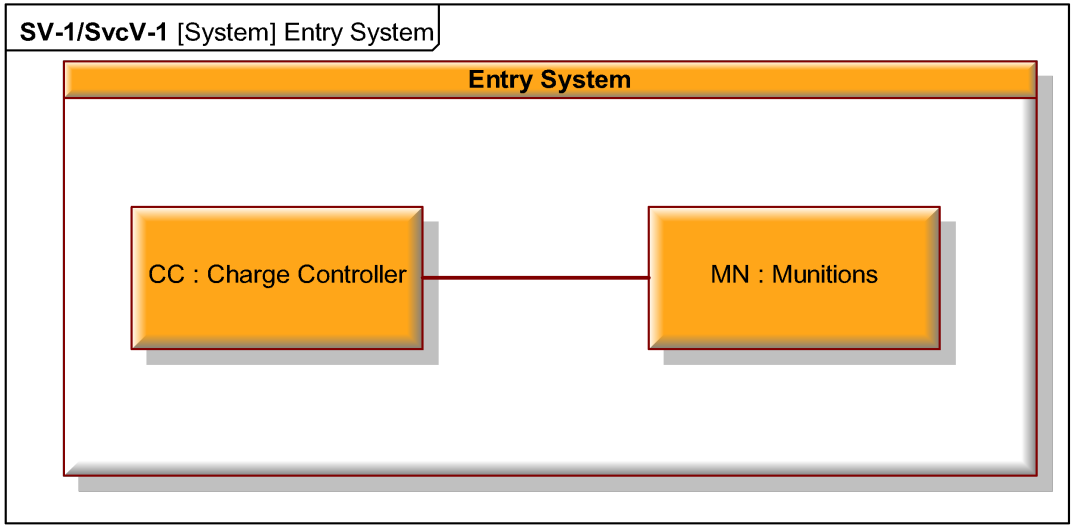
Kidnap Context Systems



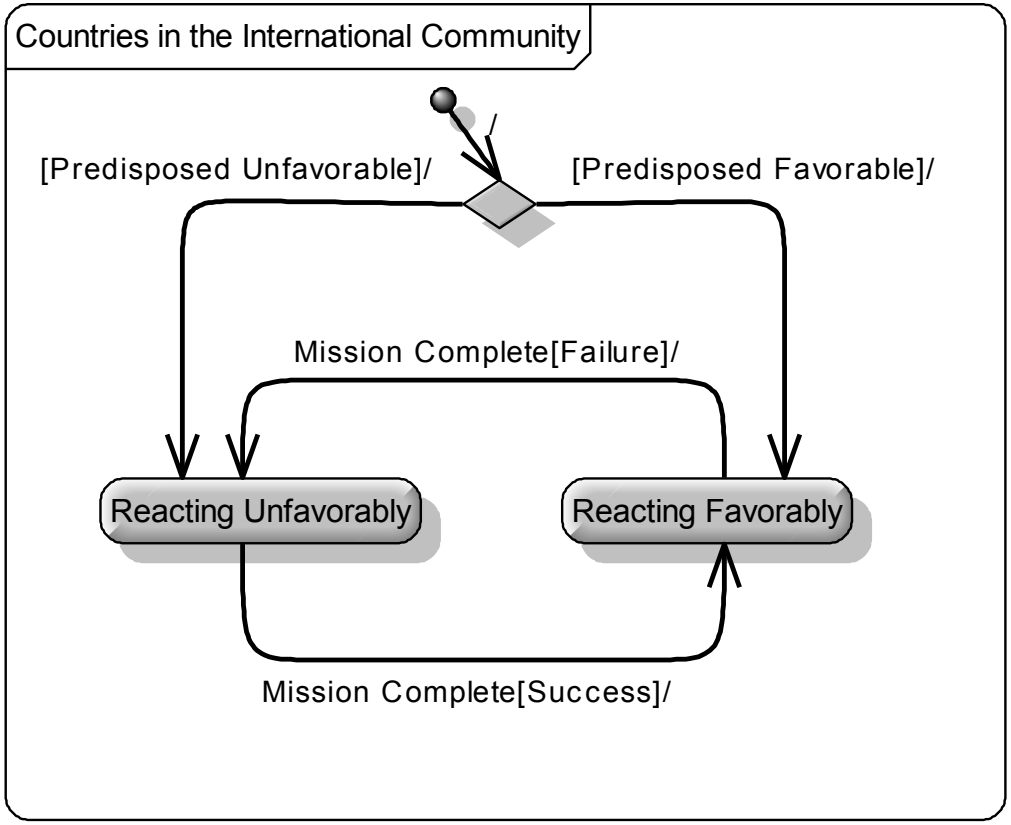
Kidnap Rescue System Context



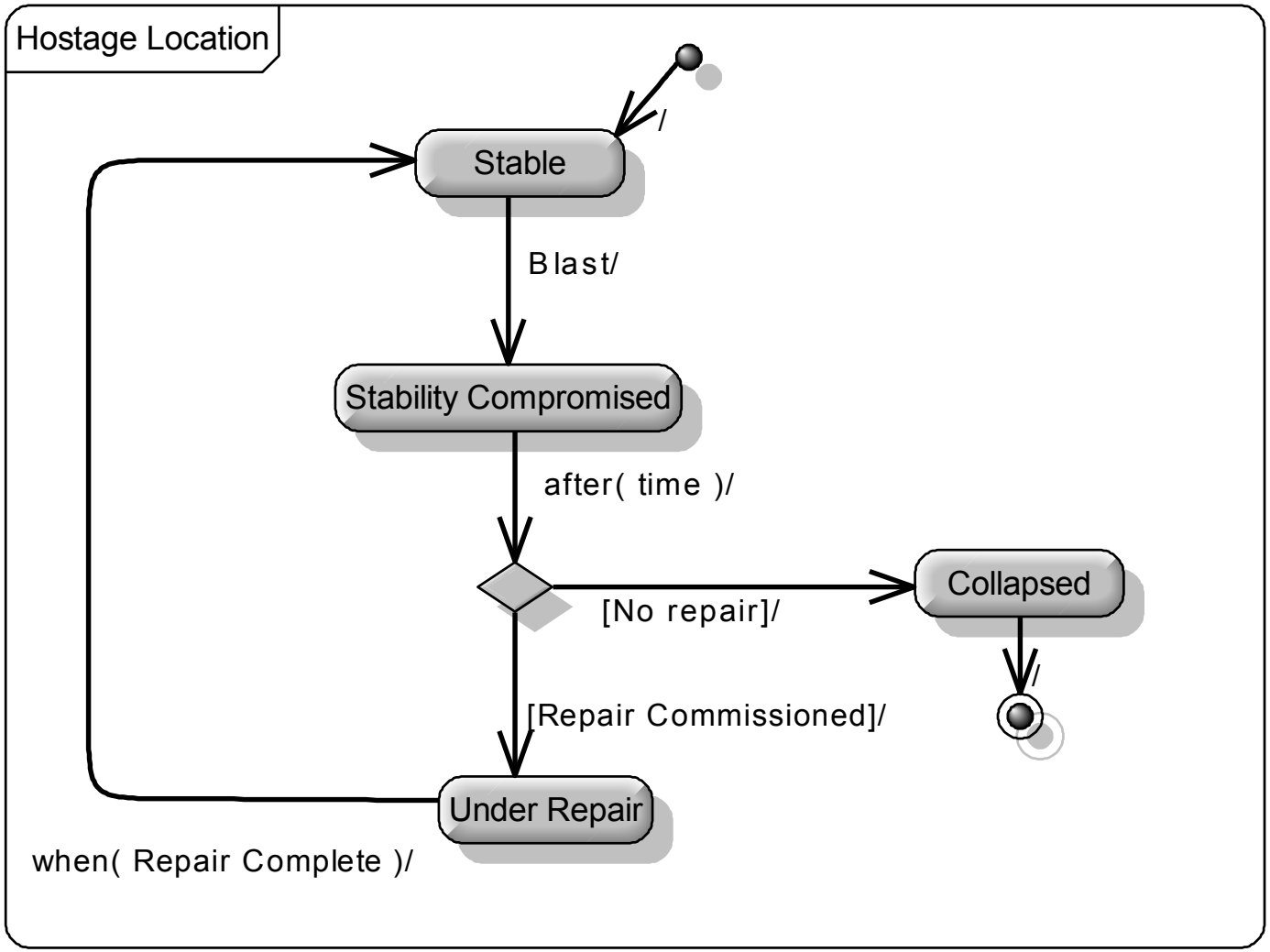
Building Entry System



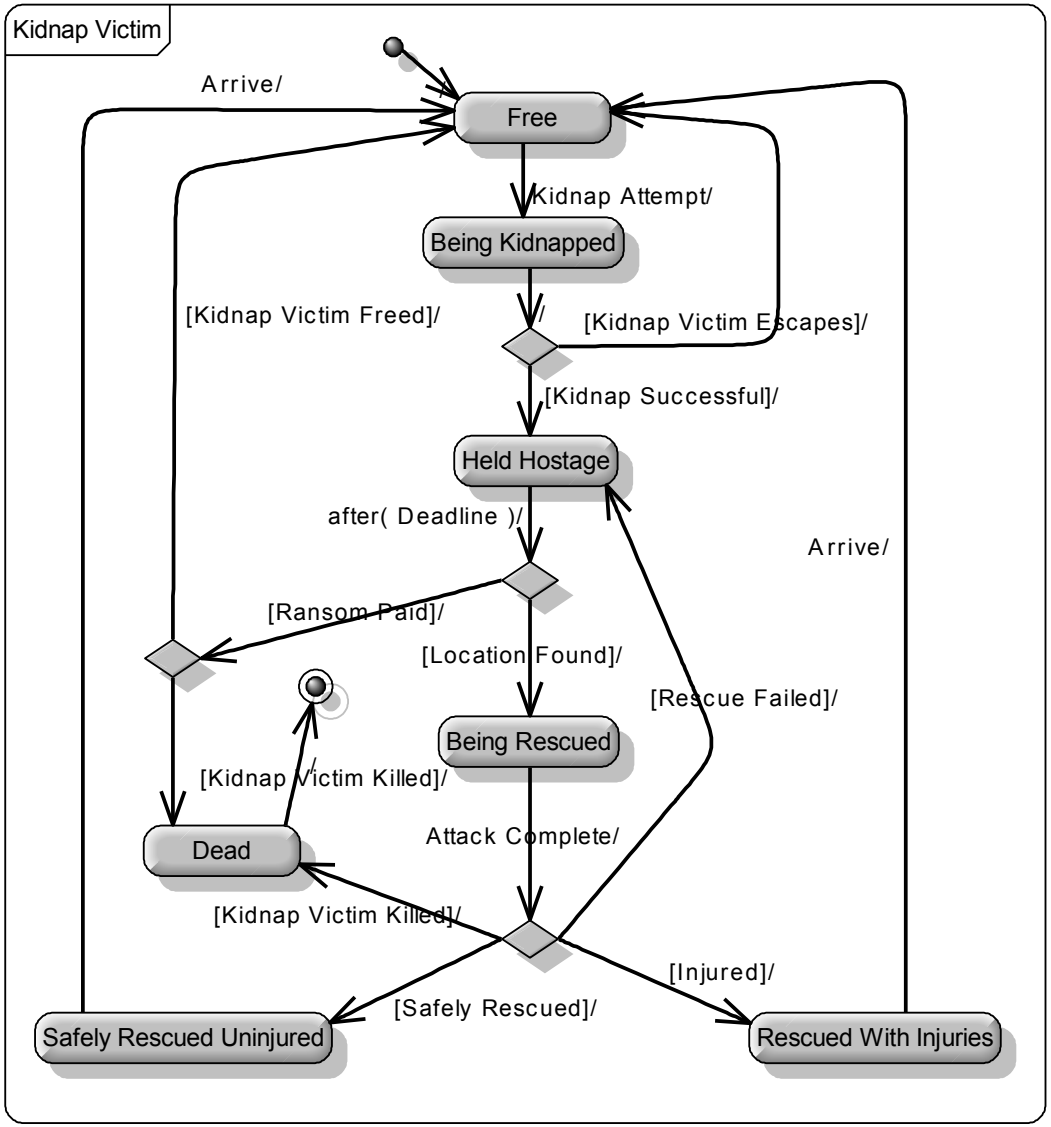
Foreign Government States



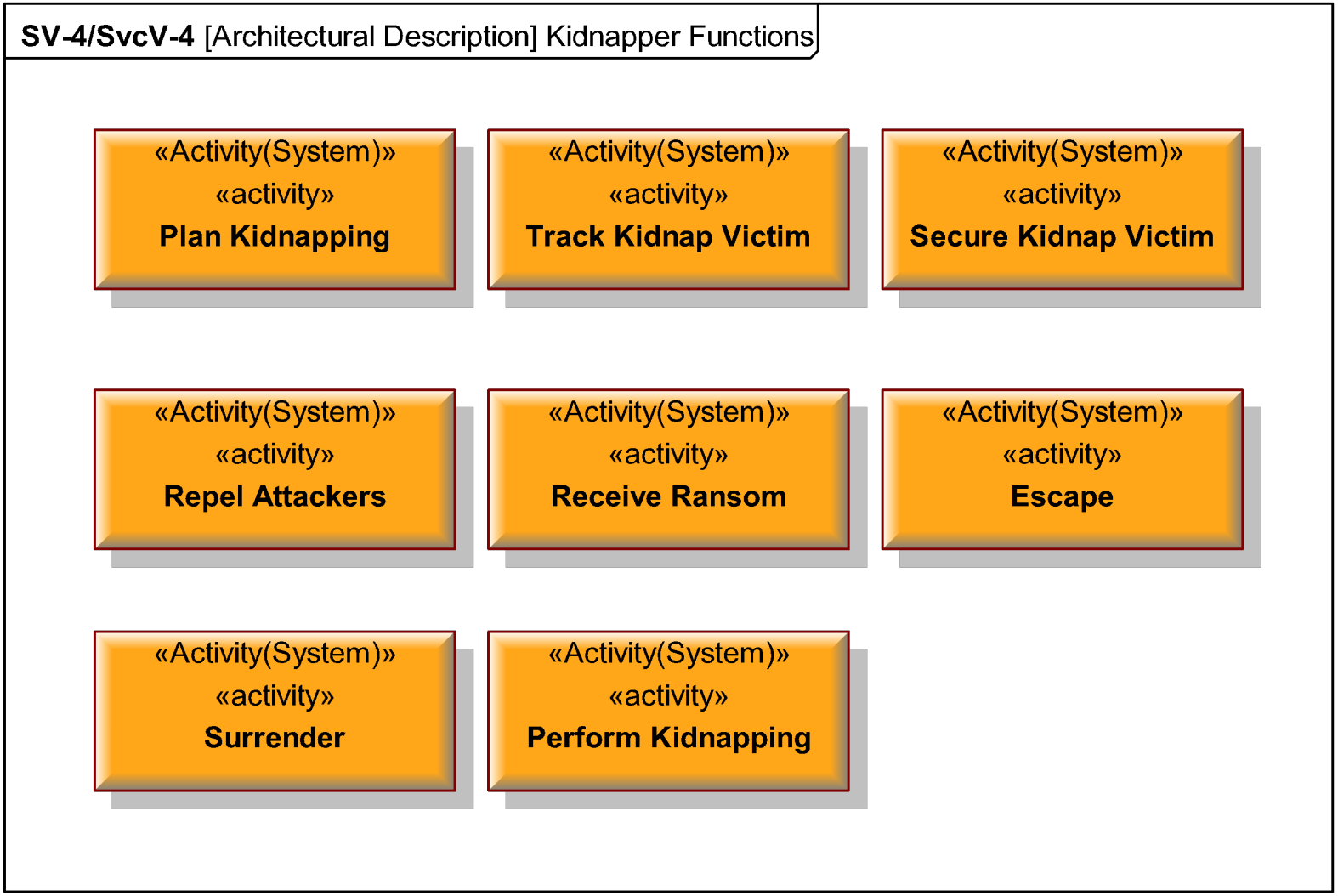
Hostage Location (Building) States



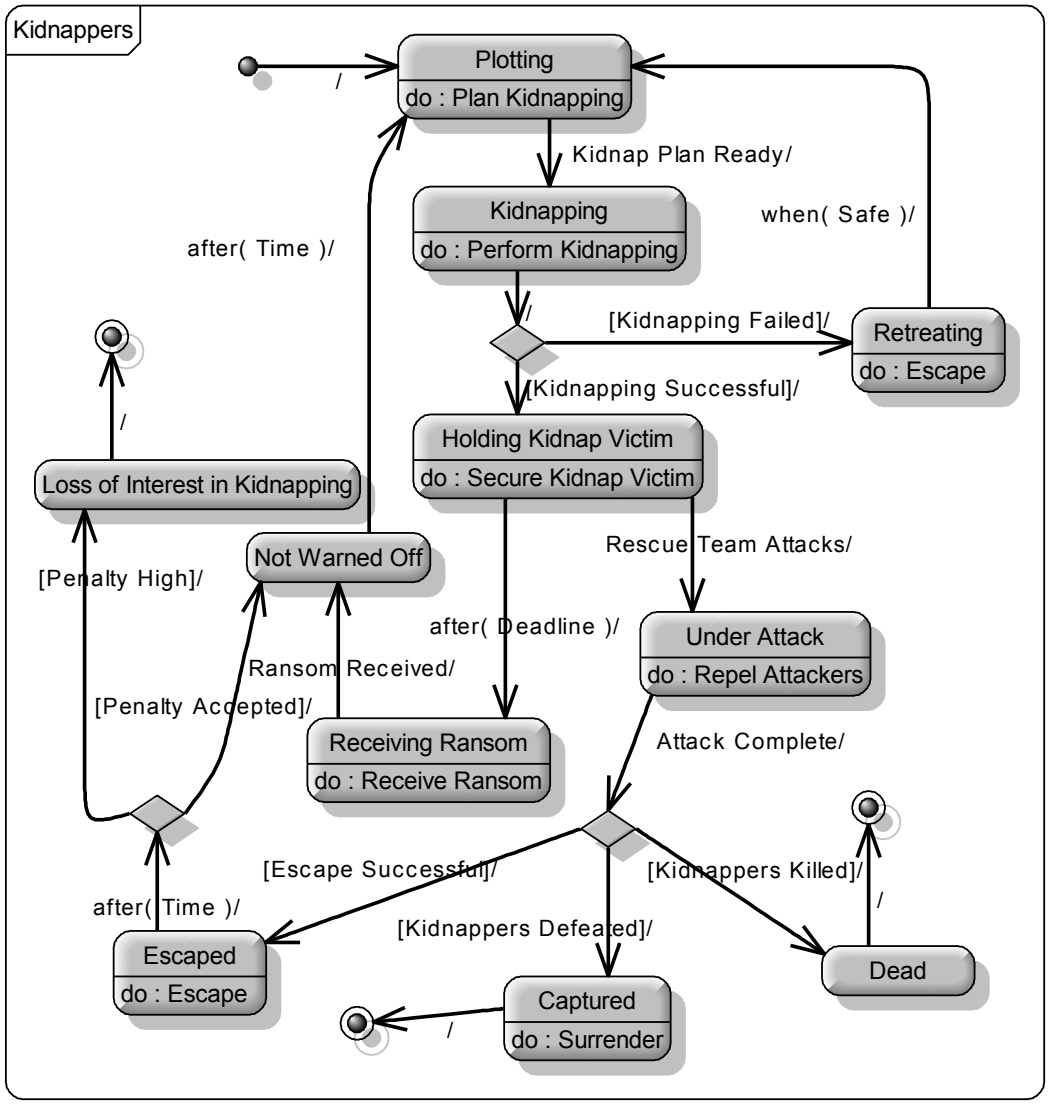
Kidnap Victim States



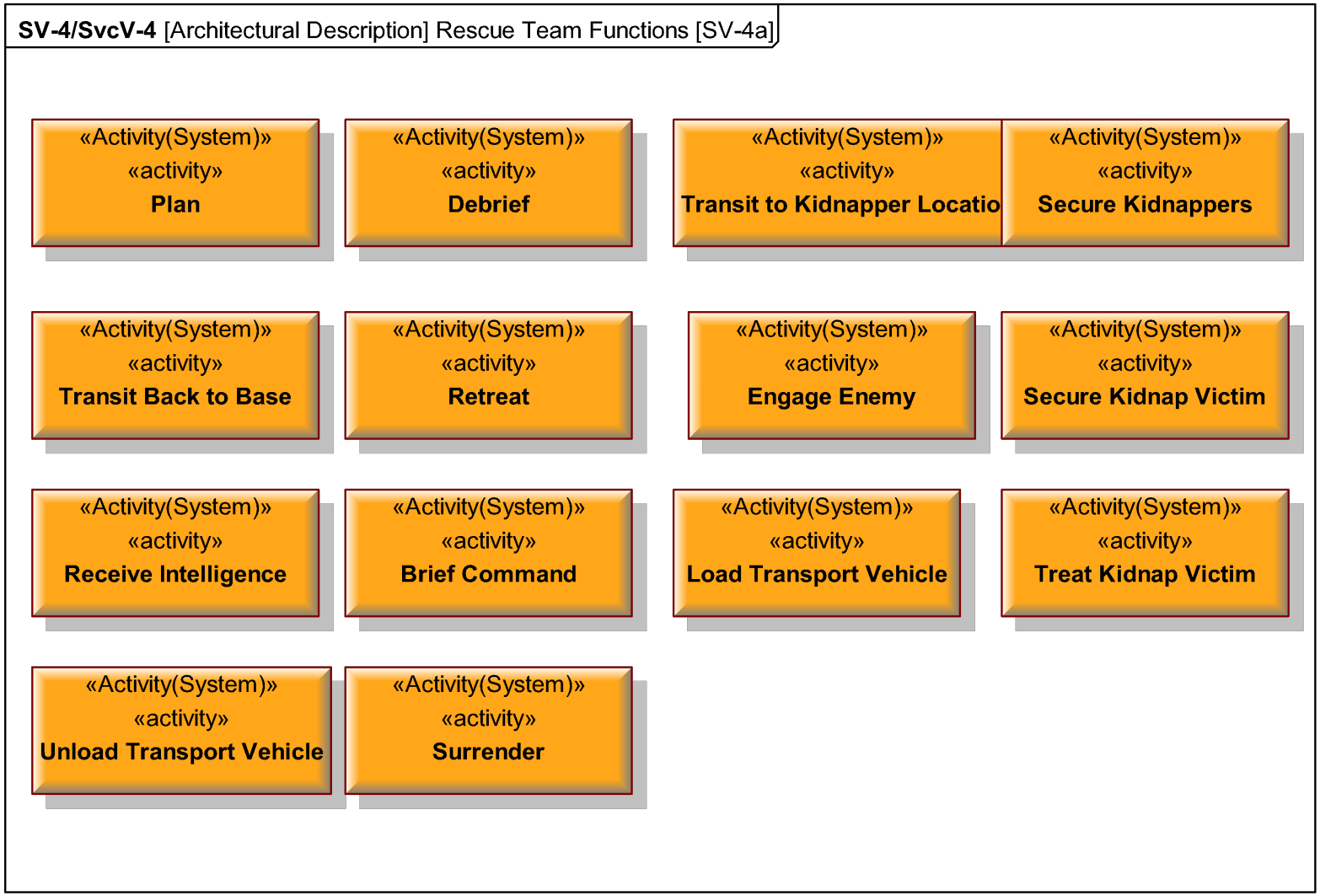
Kidnapper Functions



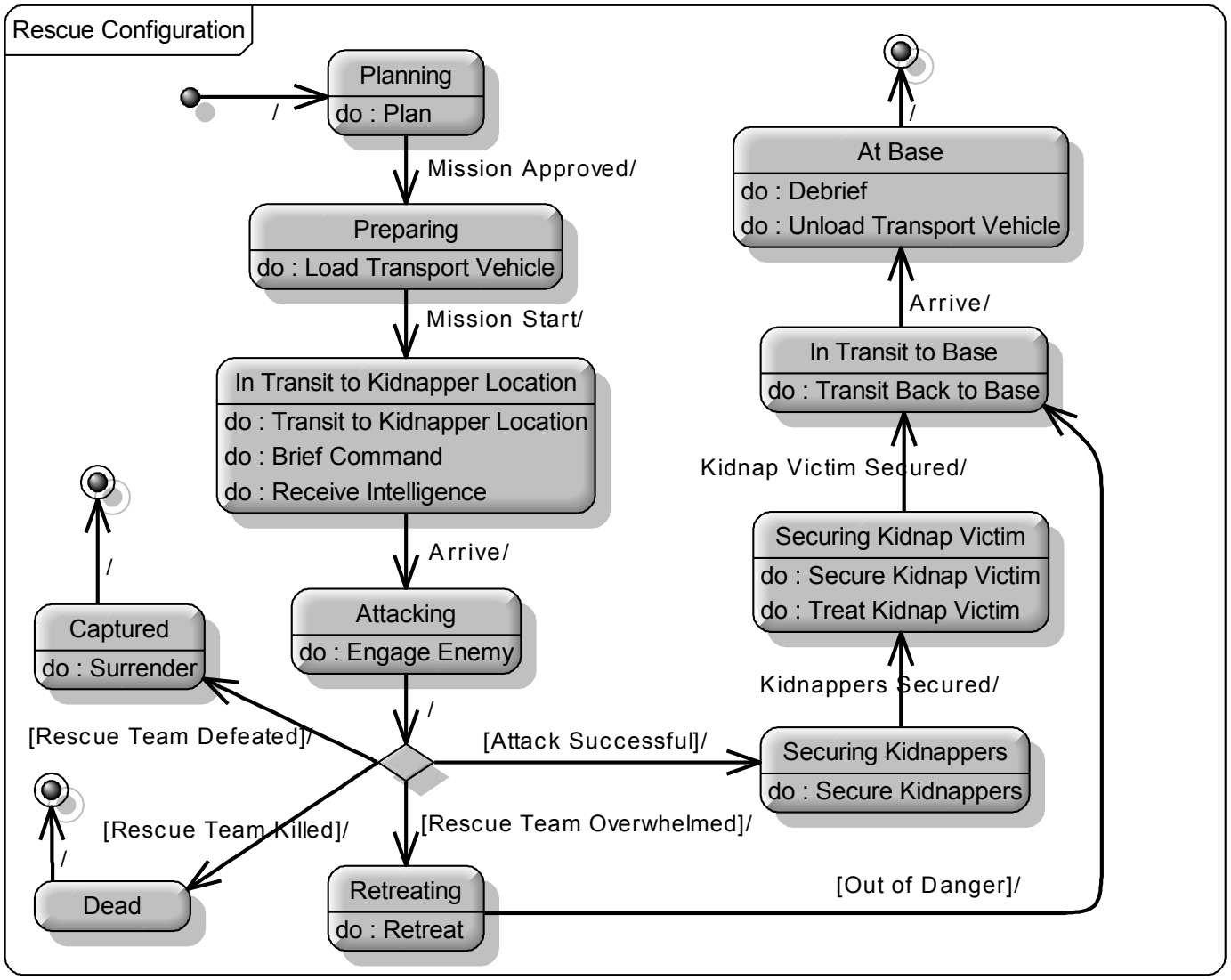
Kidnappers States



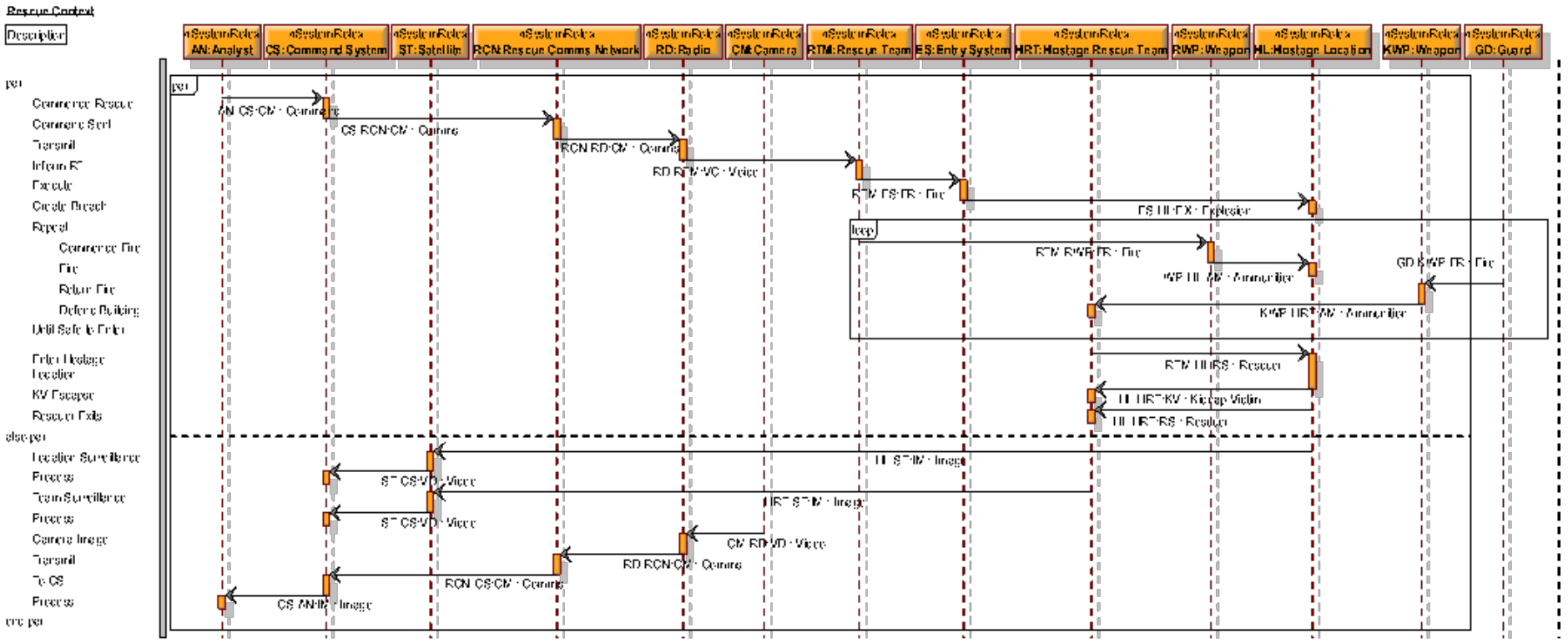
Rescue Configuration Functions



Rescue Configuration States



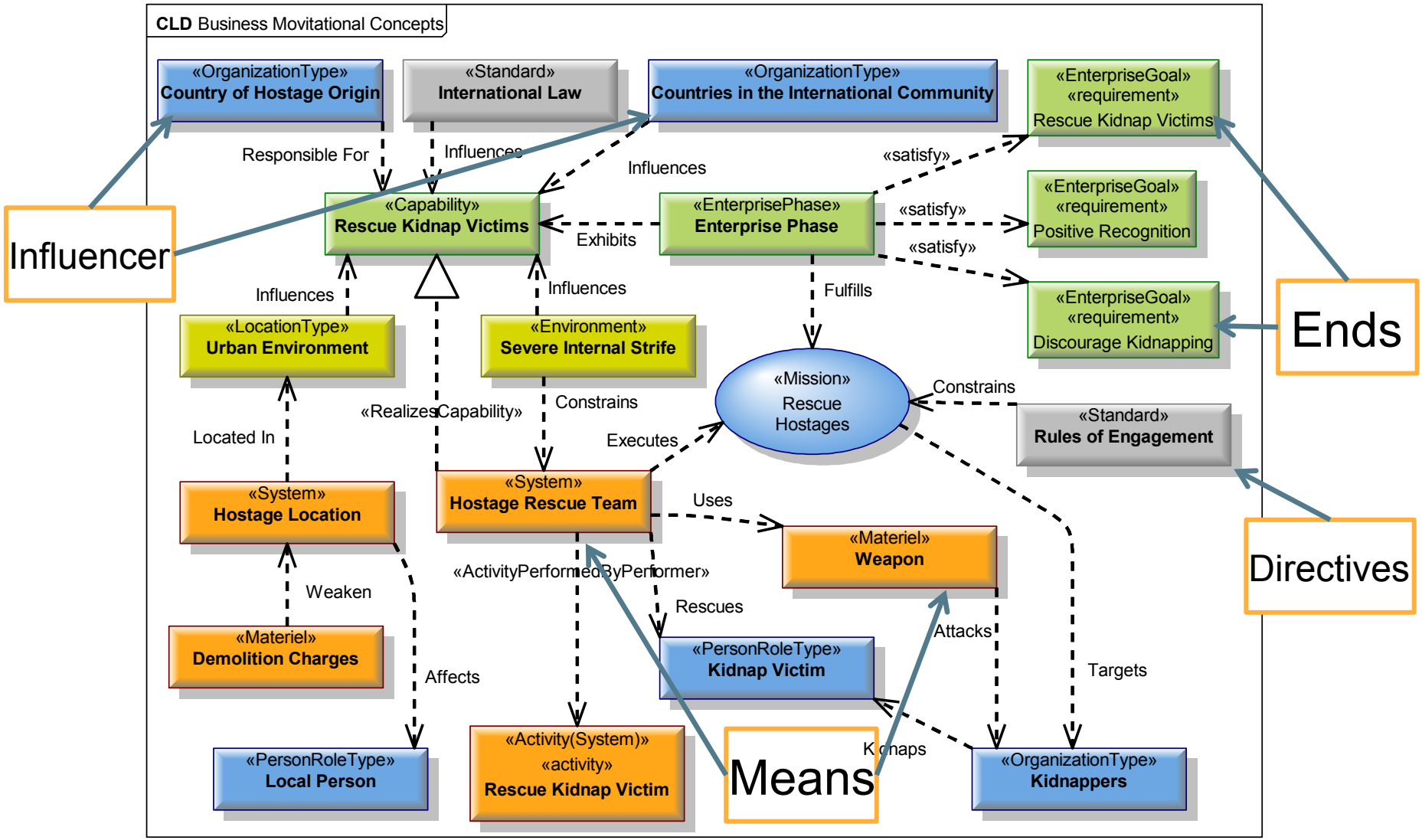
Rescue Sequence (Simplified)



Business Motivational Modeling (BMM)

- The OMG Business Motivation Model (BMM)
  - "BMM captures business requirements across different dimensions to rigorously capture and justify why the business wants to do something, what it is aiming to achieve, how it plans to get there, and how it assesses the result." [OMG, 2010]
- The main elements of BMM are:
  - Ends: What (as oppose to how) the business wants to accomplish
  - Means: How the business intends to accomplish its ends
  - Directives: The rules and policies that constrain or govern the available means
  - Influencers: Can cause changes that affect the organization in its employment of its Means or achievement of its Ends. Influencers are neutral by definition.
  - Assessment: A judgment of an Influencer that affects the organization's ability to achieve its Ends or use its Means.

BMM Concepts in DoDAF

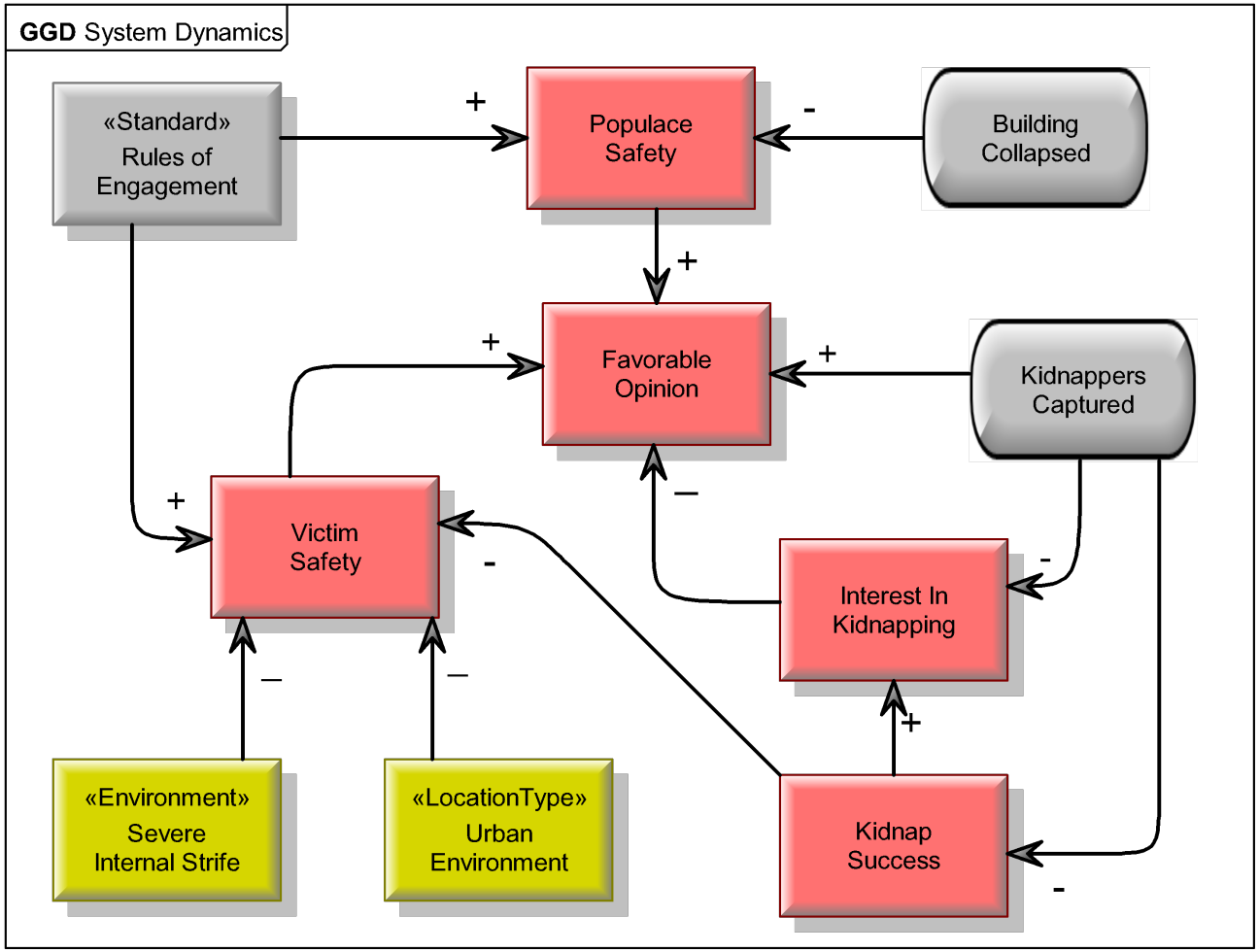


System Dynamics

- System dynamics is an approach to understanding the behavior of complex systems over time. It deals with internal feedback loops and time delays that affect the behavior of the entire system
- They are a potent tool to:
  - Teach system thinking concepts
  - Analyze and compare assumptions about the way things work
  - Gain qualitative insight into the workings of a system or the consequences of a decision
  - Recognize dysfunctional systems
  - Analyze system interactions and influences
- Normally simulation is used to assist in the analysis

System Dynamics

- Models the relationships between the system elements
- Example diagram uses states, value properties, rules and environment
- Many more objects and relationships are possible



Conclusion and Summary

- Understanding causal sequences is critical to systems engineering and architecture
- These sequences can be modeled in DoDAF/MODEM
- Simulating the sequences aids in understanding
- Different representations are required for different audiences

Questions, Comments, Discussion

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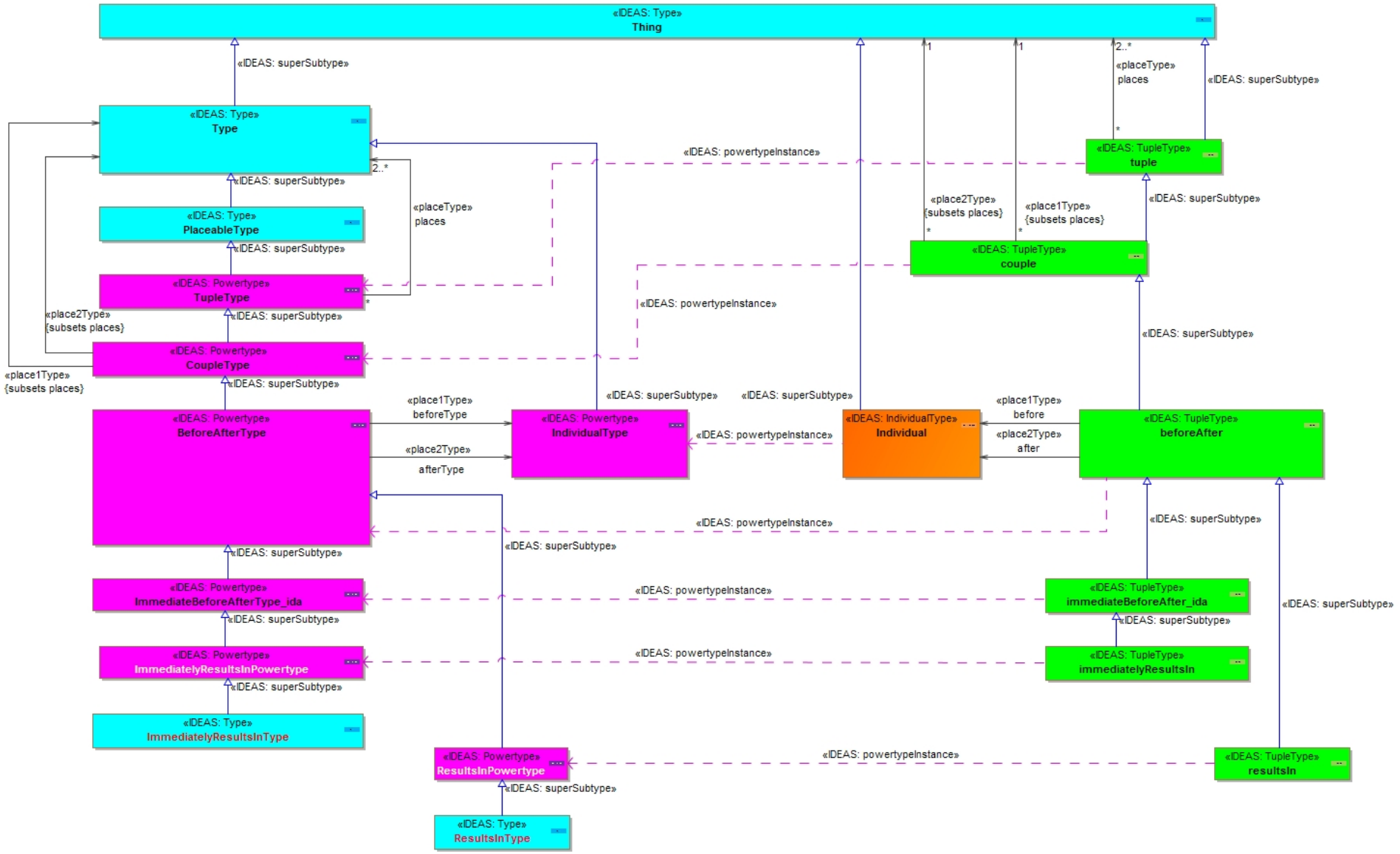
Motivating argument for the effect connections



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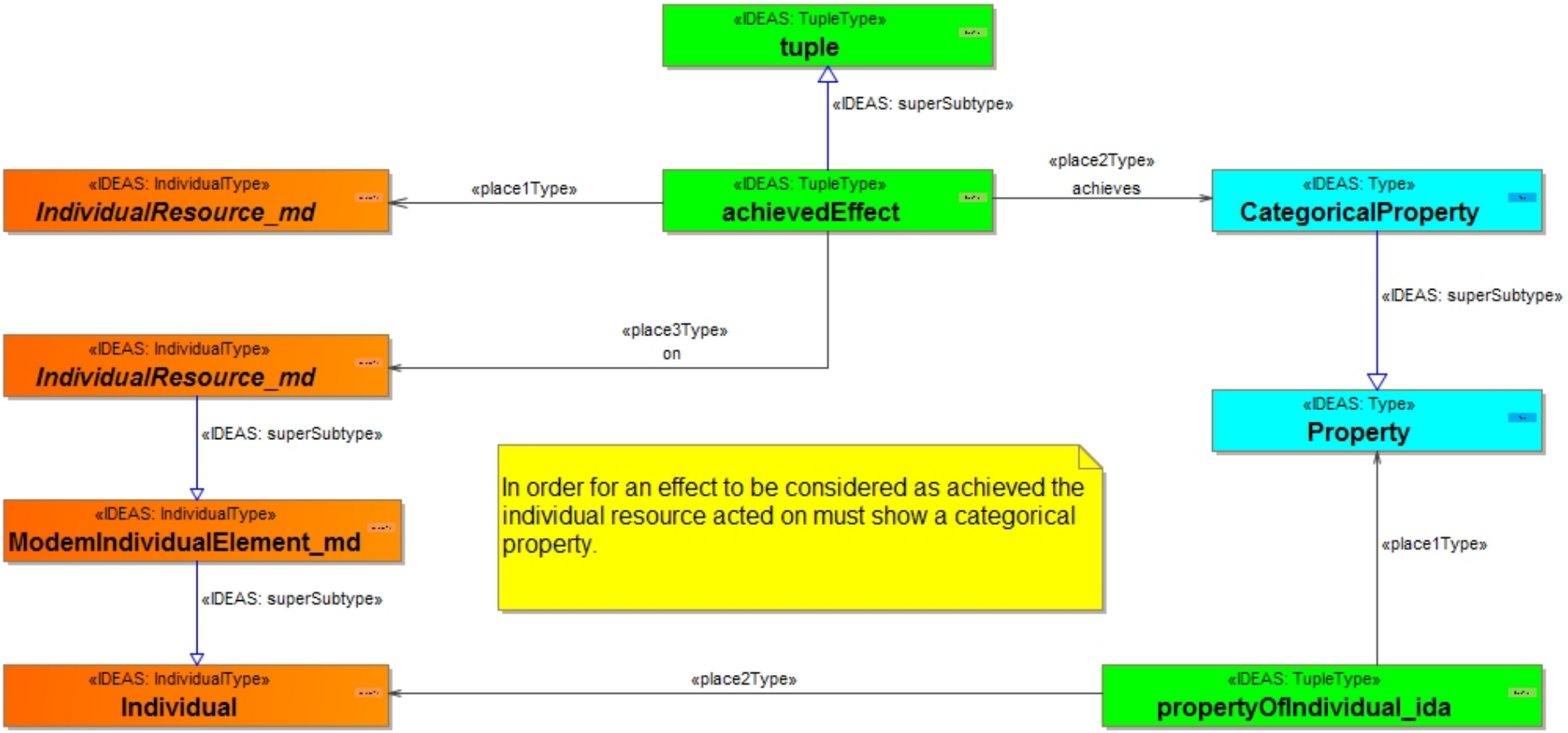
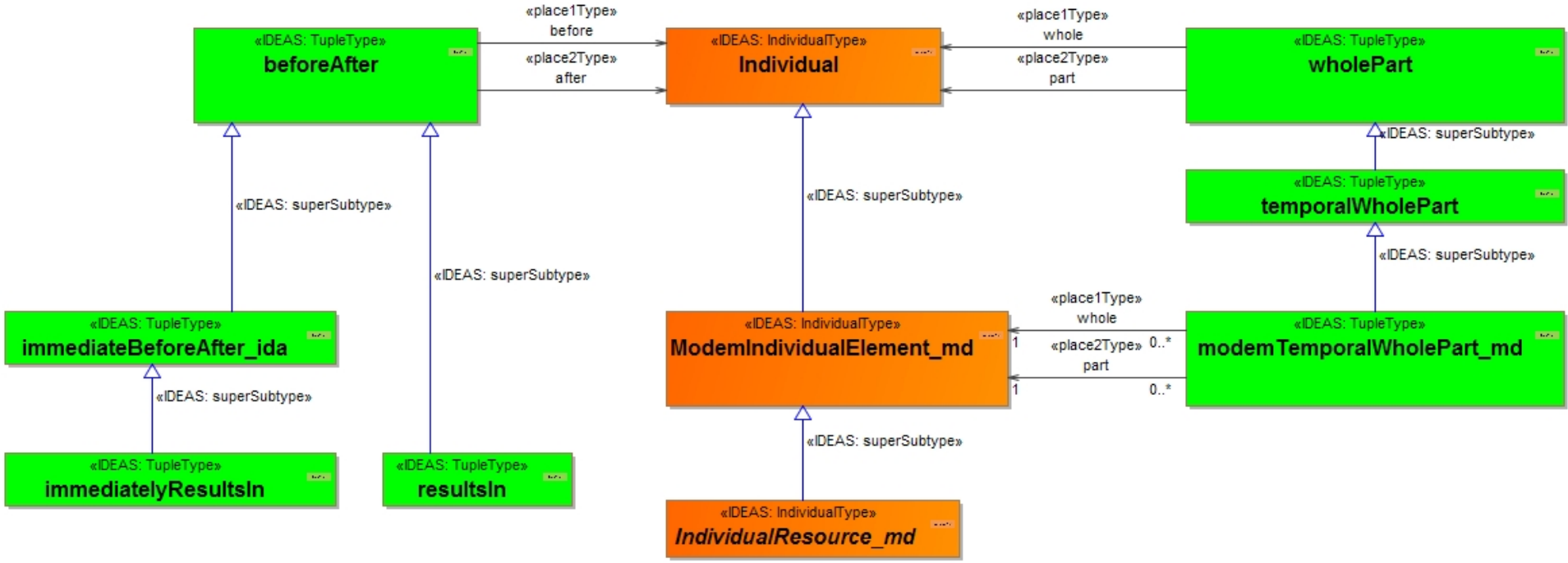
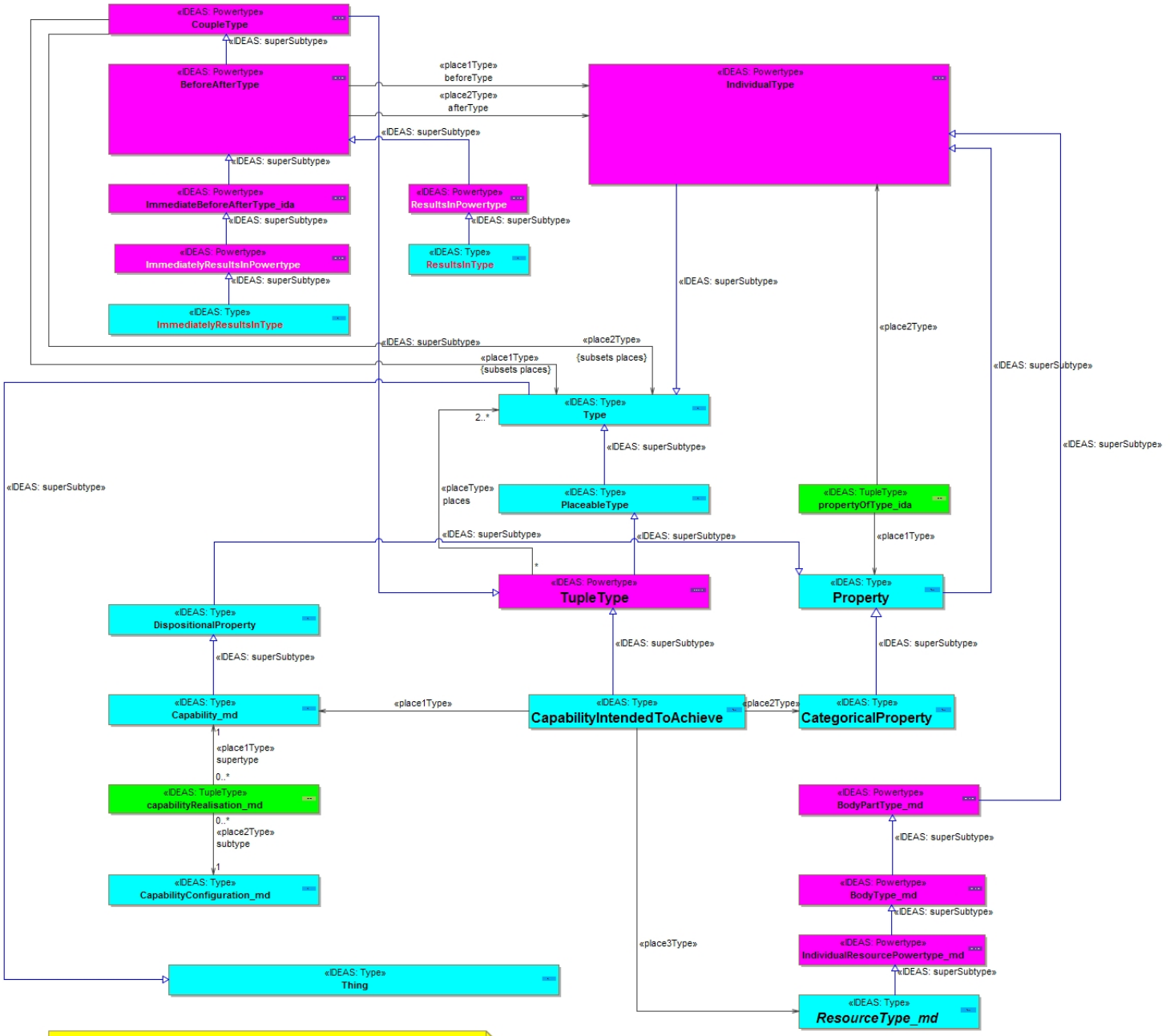
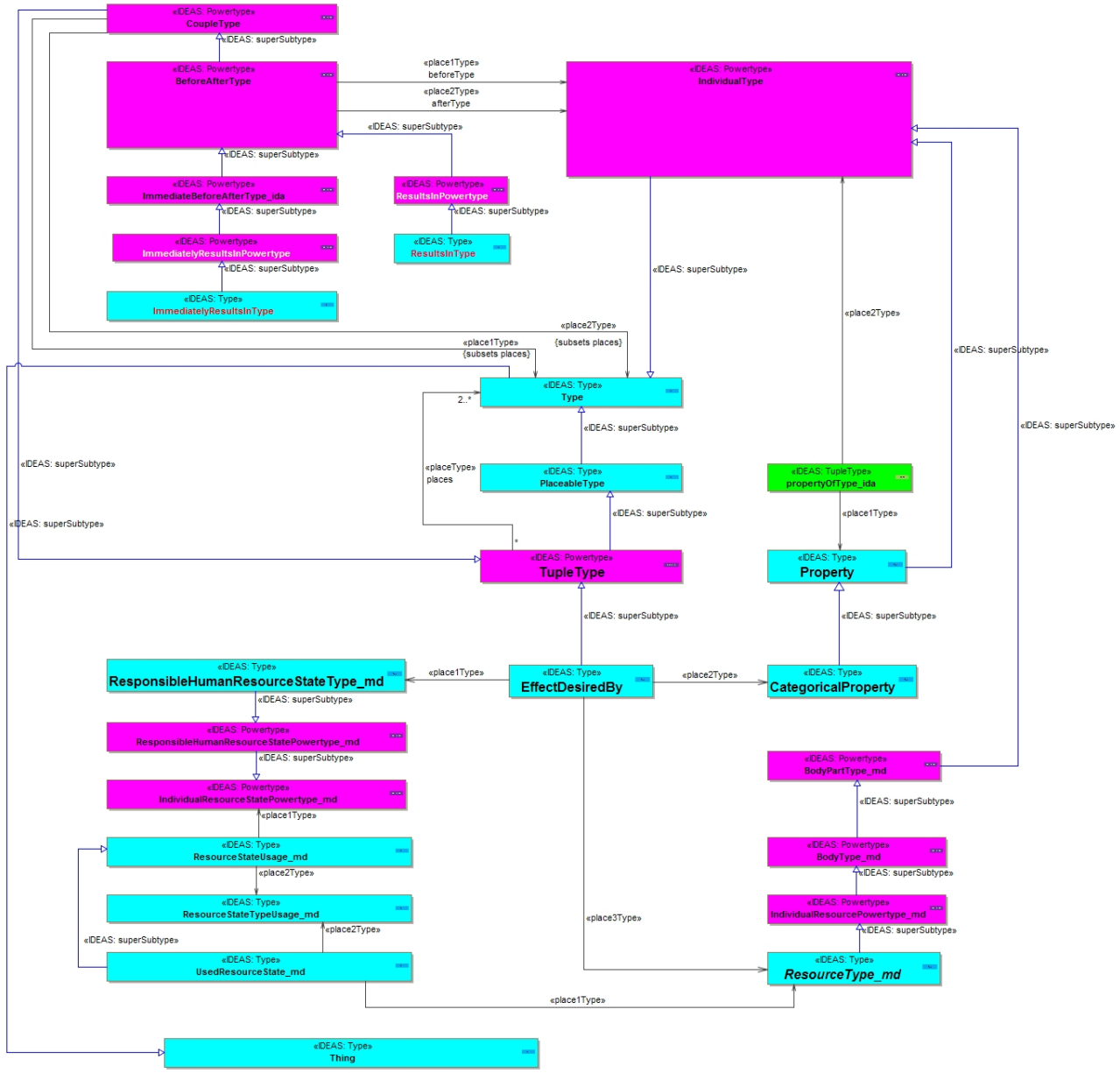




There are temporal parts of at most two individual resources where it can be stated that one temporal part of one resource ends before the other starts and where it is determined that the temporal part of one immediately results in the other temporal part or just results in the other.



This rather complex diagram traces the connections between al the elements involved in this representation and it shows that a property of type need to tie the affected resource type to the categorical property and that a ResultsInType or an ImmediatelyResultsInType relationship should exist between the resource types that exhibits the categorical property and the CapabilityConfiguration (a subset indirectly of ResourceType).



This rather complex diagram traces the connections between al the elements involved in this representation and it shows that a property of type need to tie the affected resource type to the categorical property and that a ResultsInType or an ImmediatelyResultsInType relationship should exist between the resource type affected and the ResourceType that after a somewhat elaborate connection can be found as being used by the phase of the responsible human resource.