An Automated Data Fusion Process for an Air Defense Scenario

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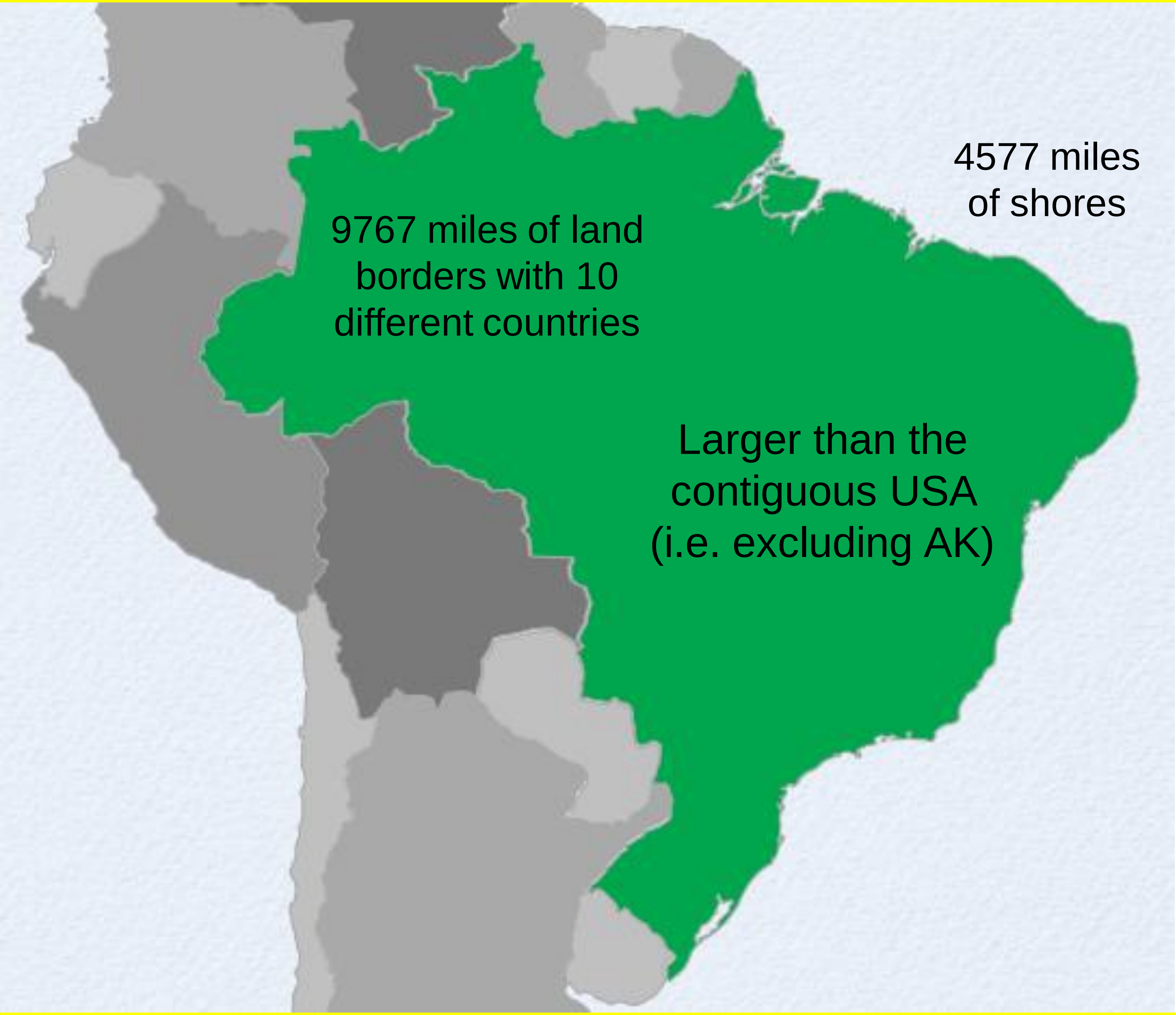
ROADMAP

- ✓ INTRODUCTION
- ✓ BACKGROUND
- ✓ SIMULATION AND ANALYSIS
- ✓ CASE STUDY: TYPICAL AIR DEFENSE SCENARIO
- ✓ CONCLUSION

Some facts about Brazil



Chronology of the Brazilian Air Defense System:

1969 – Brazilian Airspace Defense System (SISDABRA).

1969 – First Integrated Air Control Centre (CINDACTA-I).

1982 to 2005 – CINDACTA-II to CINDACTA-IV.

1998 – Brazilian Congress approved the Law 9.614 of the Destruction Shot.

2004 – Law 9614 ruled out by Decree-Law No. 5.144.

- After 2004, the BAF must enforce the “destruction shot” law, having as consequence:
  - Air authorities face high-stake decisions within an environment prone to information deluge.
  - Wrong decisions can lead to criminal charges to decision makers and pilots.
  - The BAF must improve its airspace policing procedures.

- Major priority in this new scenario:
  - Combining information from various sources to generate knowledge in support to actionable decisions.

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BACKGROUND

Technologies and concepts used in this work to address the Air Defense challenge

Petri Net

- Identify the processes involved in decision making.
- Formalize the process, variables and their dependencies.
- Identify the source of information (variables).

Ontology

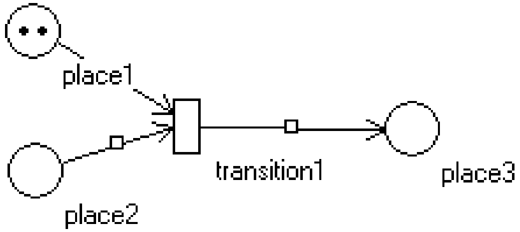
- Identify the concepts and relationships involved in the scenario.
- Formalize the concepts.
- Interoperability.

Rules and Inferences

- Information processing, generating new knowledge.

Petri Net – PN

- Mathematical modeling tools applicable to various discrete time situations.
- Graphic interface allows visualizing the flow of actions as they unfold.

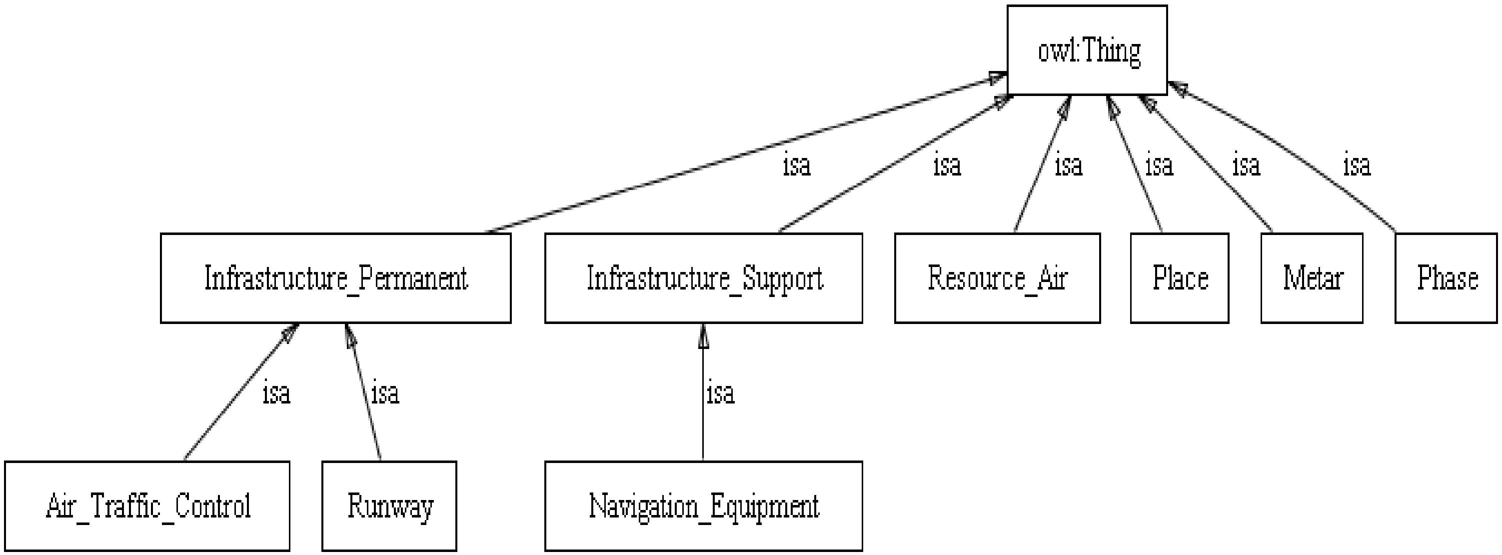


- Transitions between different phases can be mapped into mathematical equations or equations of state that define system behavior.
- This study assumes all actions and conditions have the same degree of importance in a decision-making system.
- Transitions will be enabled when their preconditions have at least one token.

Ontologies

- Are explicit and formal representations of a domain of interest.
- Can represent different concepts and their interrelationships.
- Are essential to delineate and restrict the scope of the problem and promote interoperability with other systems, allowing for information sharing.
- Can be divided in the following types: Top, Domain and Application.

In this work, we developed a *Domain Ontology* for air space policing.



Rules and decision support

- This work aims to ensure that the tasks involved in air defense system, especially for measures of policing, are closely matched by the model.
- Standardized procedures are represented as rules, which:
    - Validate information.
    - Support inferential reasoning.

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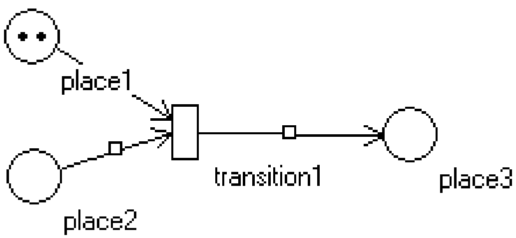
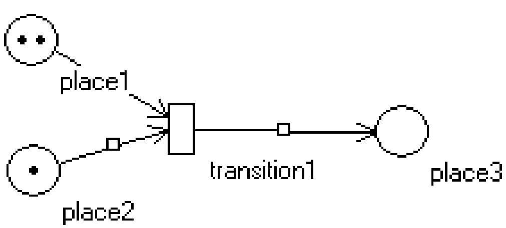
PETRI NET

1. Petri Net is a tool to ensure that all procedures related to a particular phase will be executed.
2. A *transition* is fired only when all places are associated with the minimum number of tokens required.
3. Each token, or set of tokens, represents the satisfactory implementation of an established procedure.
4. From this, the transition is fired and the next action is executed.
5. Thus, the authority will be assured that the conclusion of one phase was followed by an analysis of all parameters that define it, not leaving the possibility of forgotten or topological changes.

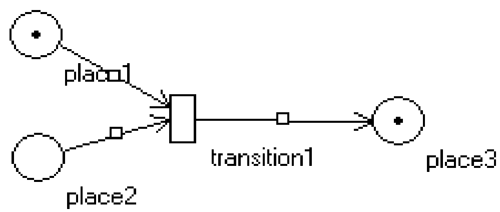
Transition not enabled

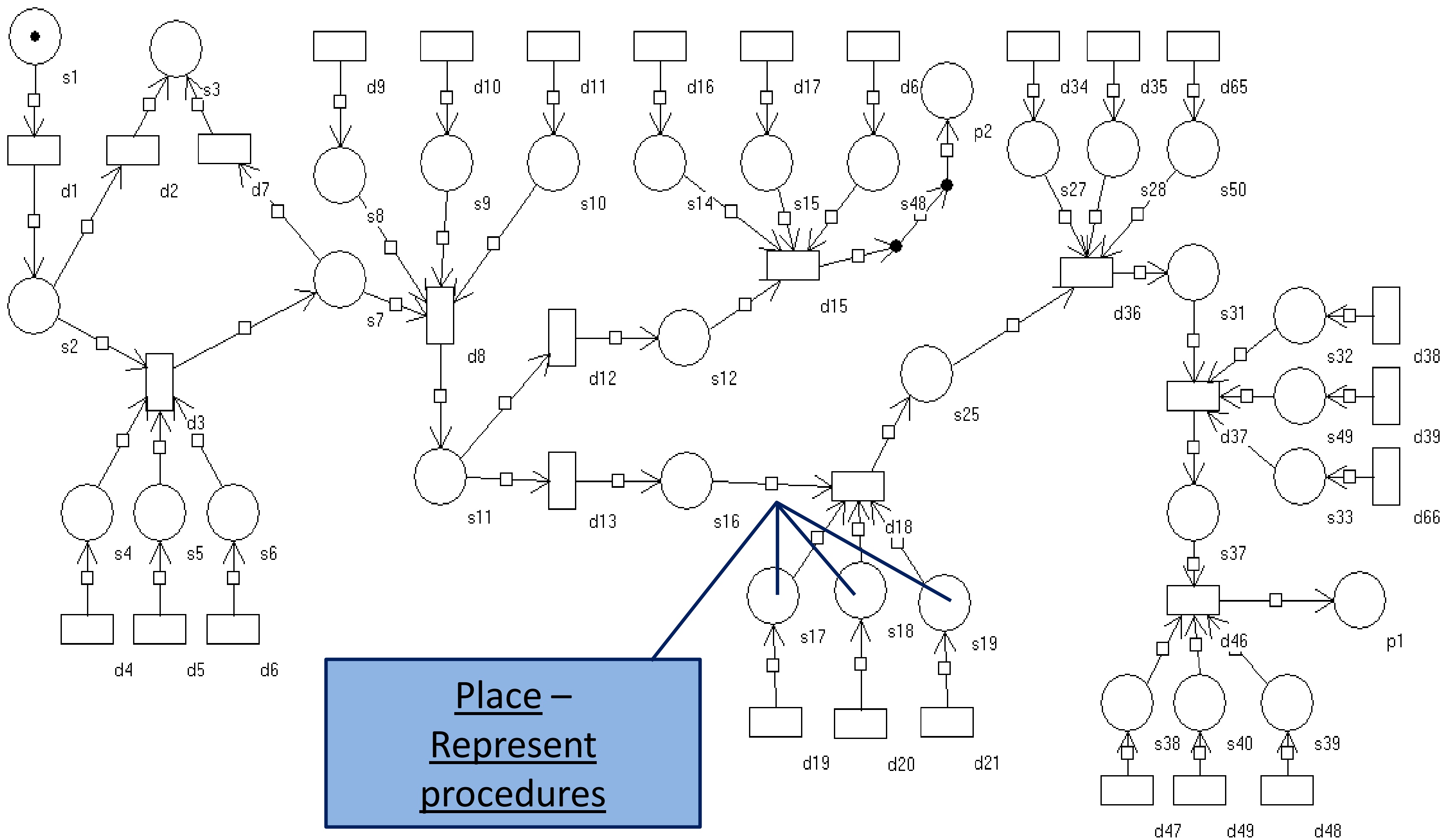


Transition enabled, but not fired

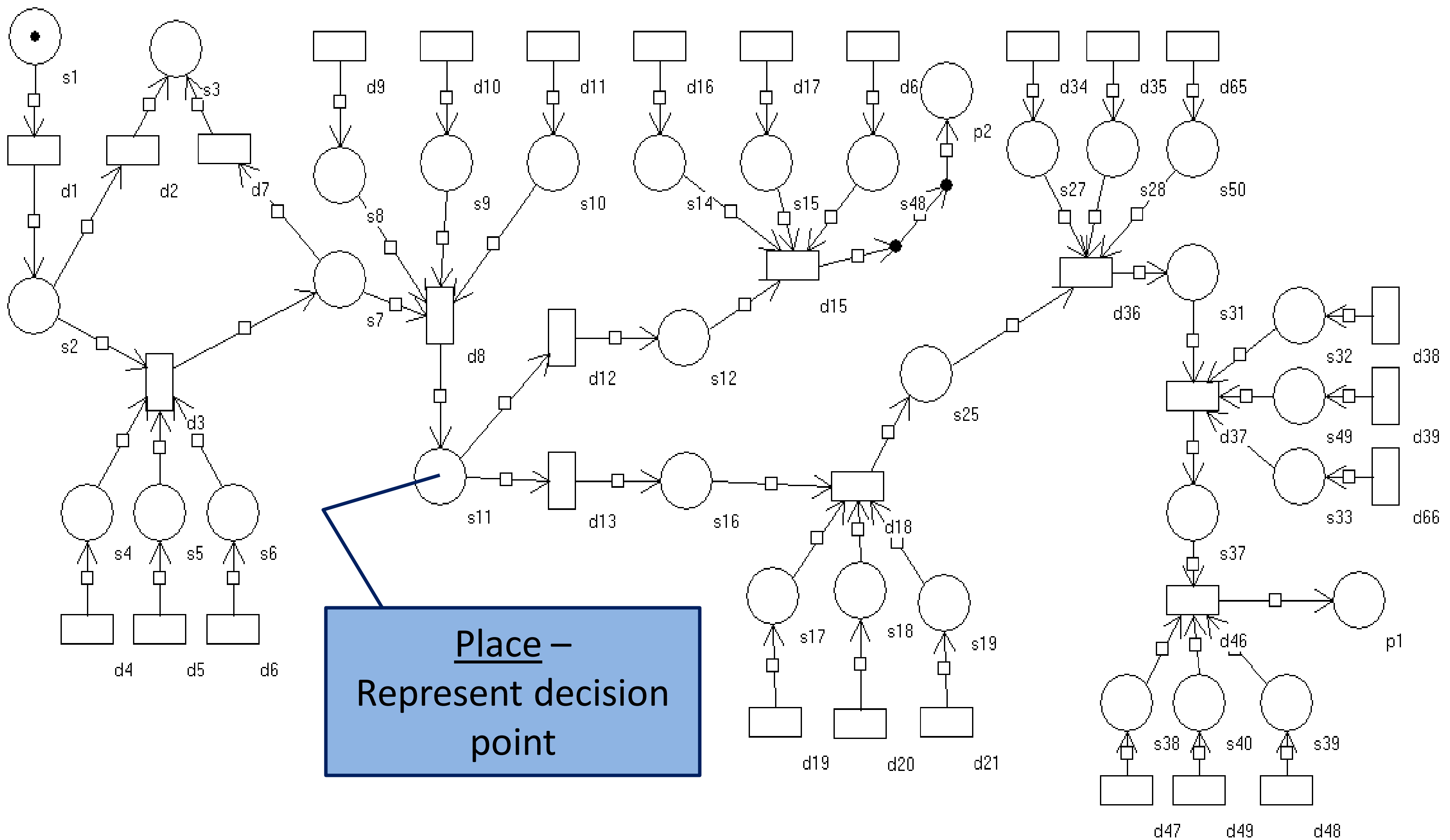


Transition after being fired





The model was constructed and simulated by using a PN simulator, where places represent procedures to be performed in the course of operations ***or*** a decision point. Transitions represent the conclusion of a phase.



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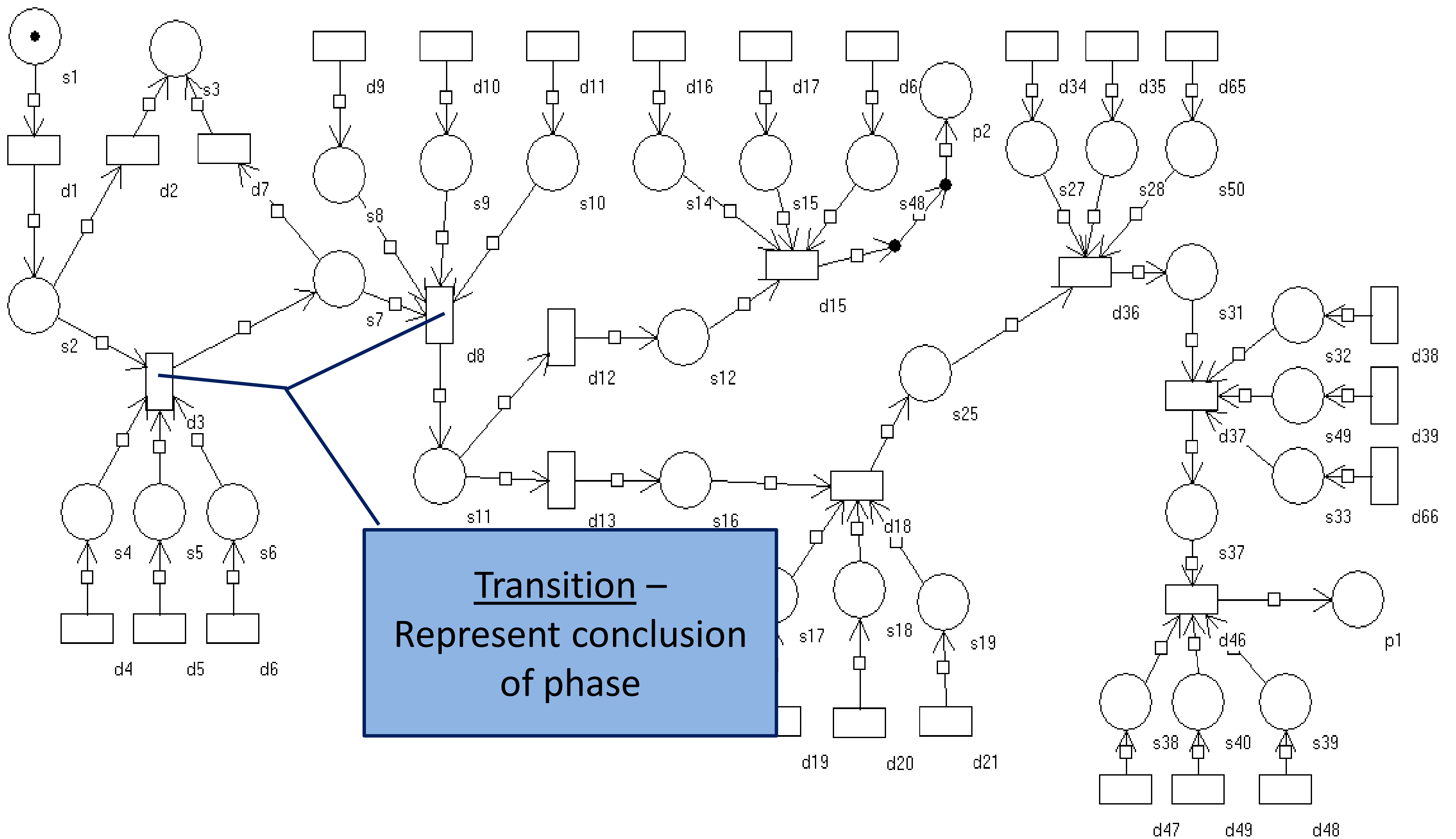
SIMULATION AND ANALYSIS



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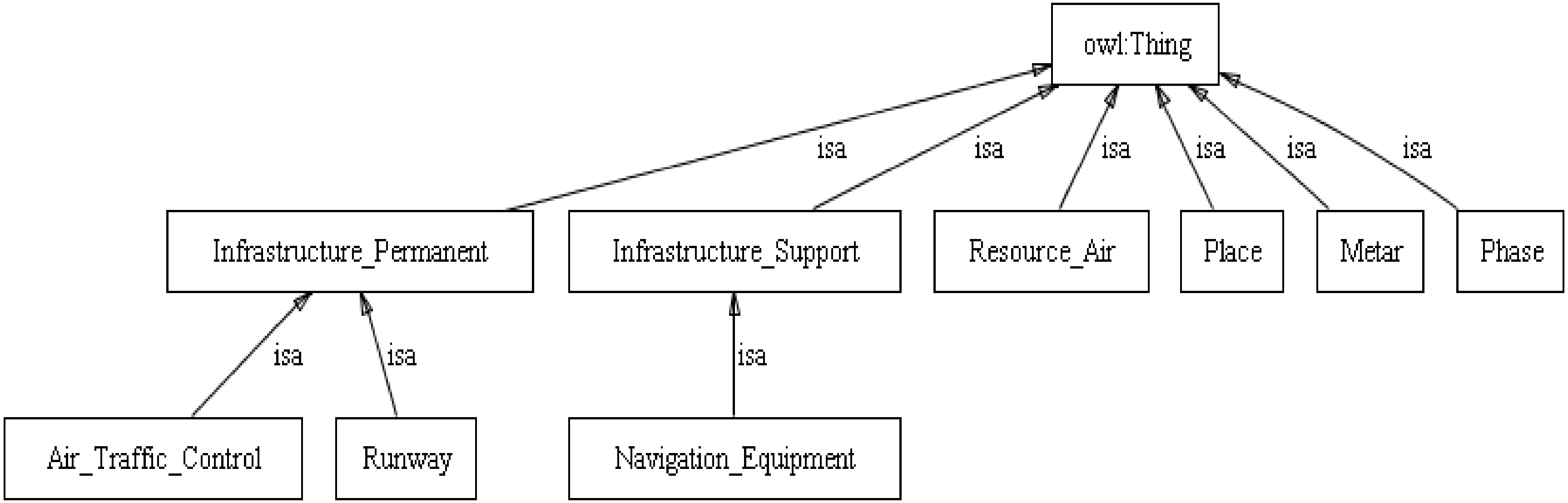
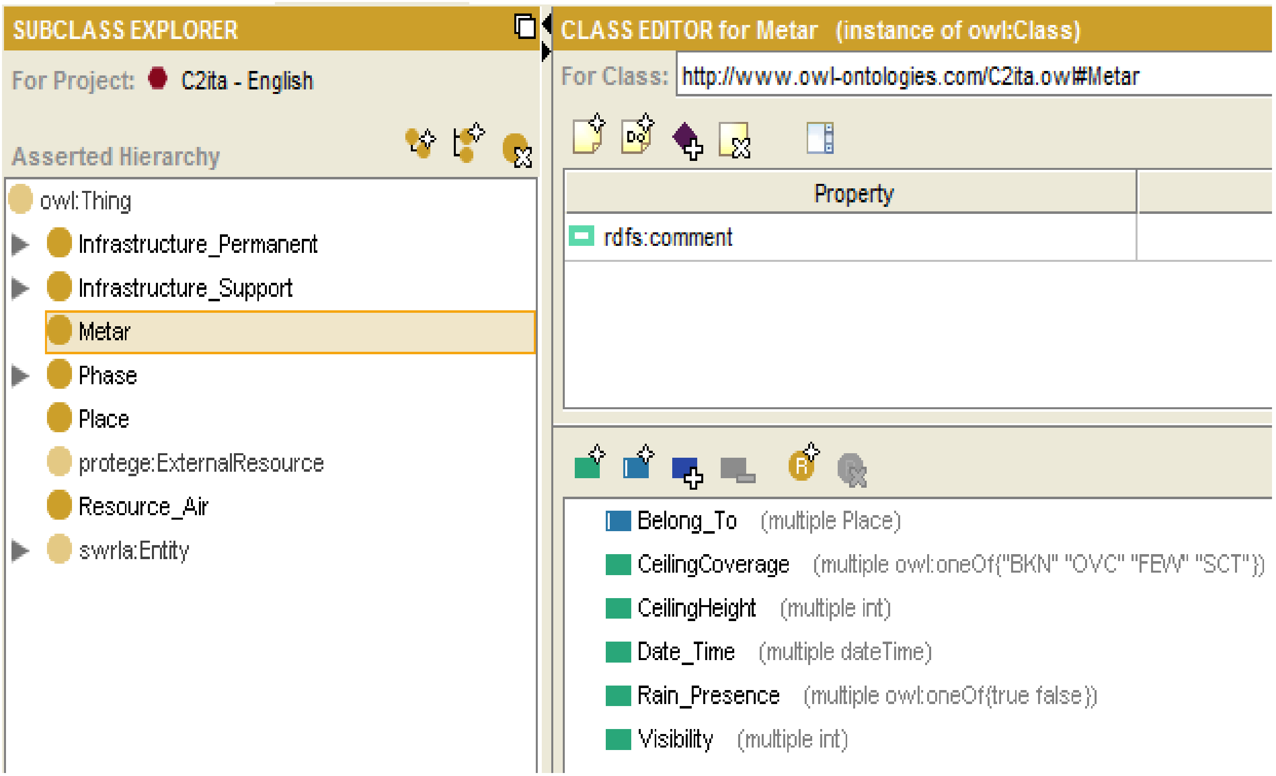
ONTOLOGY

The ontology developed for this work represents the concepts involved in the activity of Air Defense, focused on measures of air space policing to comply with legal requirements for the destruction shot.



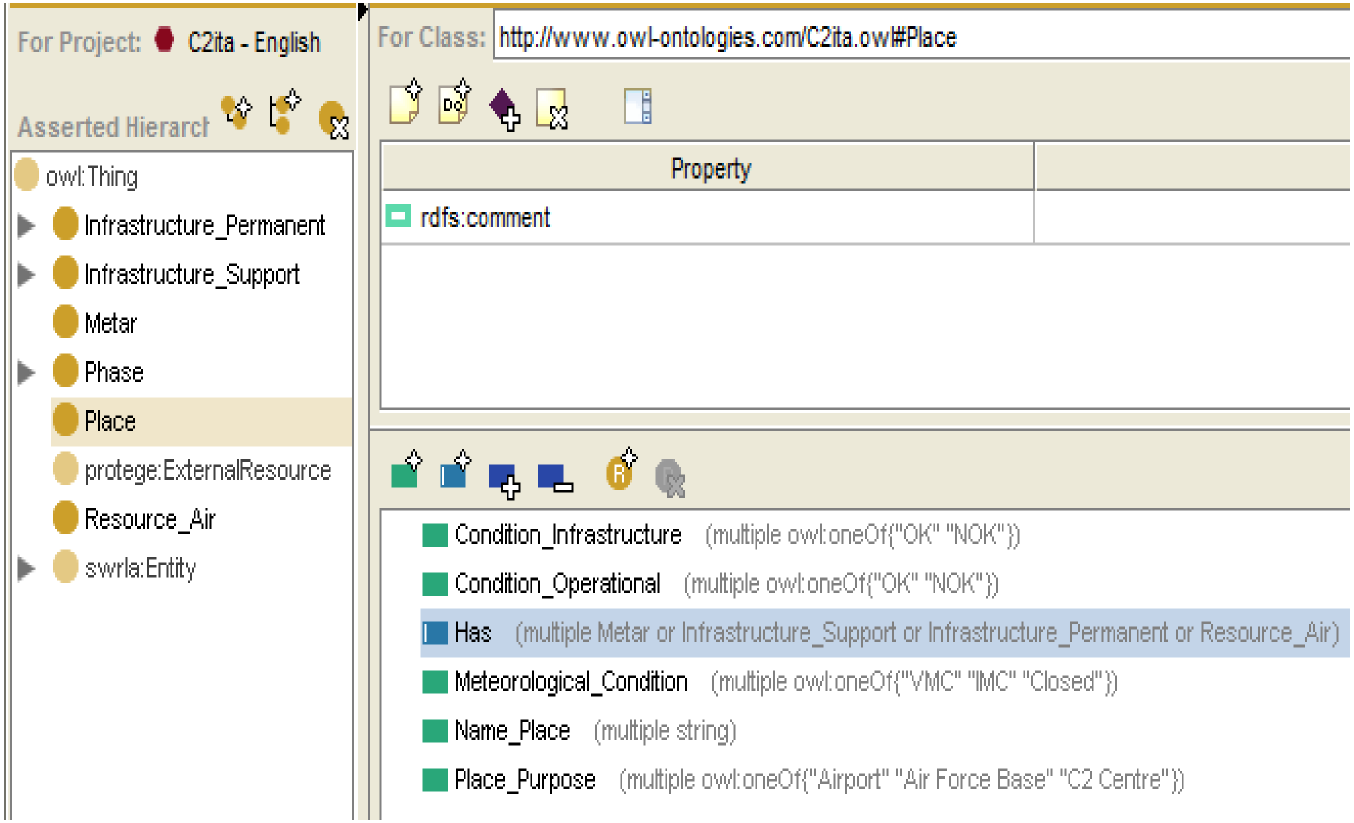
- Data on each instance of the classes represent a place within the PN.
- The Class Phase represents the transitions.

ONTOLOGY



METAR class and attribute

ONTOLOGY



Local class and attribute

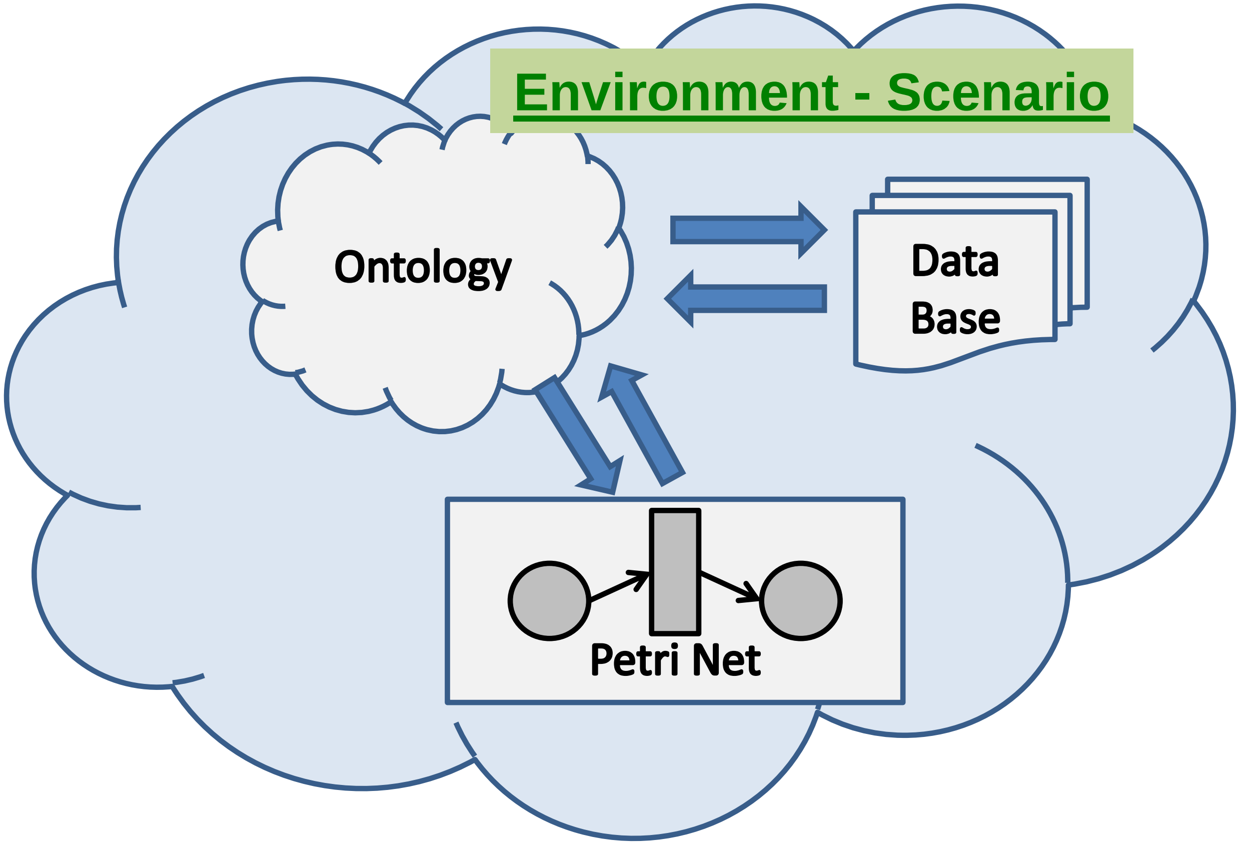
ONTOLOGY

- The model explores the view of systemic processes inherent to the analyzed activity.
- The ontology was structured to:
  - store information.
  - make inferences about this information.
  - expand the knowledge base on the domain.
- The rules are defined by SMEs from the Air Space domain.
- The inferential process supported by the rules implemented in the ontology using SWRLJess provides a higher level of automation and minimize human errors.

SWRL Rules

...	Name	Expression
☑	Closed_Ceiling	Place(?loc) ∧ Metar(?met) ∧ Belong_To(?met, ?loc) ∧ CeilingCoverage(?met, ?cob)∧ swrlb:notEqual(?cob, "FEW") ∧ CeilingHeight(?met, ?alt) ∧ swrlb:lessThan(?alt, 500) → Meteorological_Condition(?loc, "Closed")
☑	Closed_Visibility	Place(?loc) ∧ Metar(?met) ∧ Belong_To(?met, ?loc) ∧ Visibility(?met, ?vis) ∧ swrlb:lessThan(?vis, 500) → Meteorological_Condition(?loc, "Closed")
☑	IMC_Visibility	Place(?loc) ∧ Metar(?met) ∧ Belong_To(?met, ?loc) ∧ Visibility(?met, ?vis) ∧ swrlb:lessThan(?vis, 5000) ∧ CeilingHeight(?met, ?alt) ∧ swrlb:greaterThanOrEqual(?alt, 500) → Meteorological_Condition(?loc, "IMC")
☑	Infrastructure_Conditio...	Place(?loc) ∧ Navigation_Equipment(?auxnav) ∧ Belong_To(?auxnav, ?loc) ∧ Navigation_Equipment_Operational_Condition(?auxnav, "NOK") → Condition_Infrastructure(?loc, "NOK")
☑	Infrastructure_Conditio...	Place(?loc) ∧ Runway(?pista) ∧ Belong_To(?pista, ?loc) ∧ Belong_To(?pista, ?loc) ∧ Runway_Operational_Condition(?pista, "NOK") → Condition_Infrastructure(?loc, "NOK")
☑	Operational_Condition...	Place(?loc) ∧ Condition_Infrastructure(?loc, ?condinf) ∧ swrlb:equal(?condinf, "NOK") → Condition_Operational(?loc, "NOK")
☑	Operational_Condition...	Place(?loc) ∧ Meteorological_Condition(?loc, ?condmet) ∧ swrlb:equal(?condmet, "Fechado") → Condition_Operational(?loc, "NOK")
☑	Operational_Condition...	Place(?loc) ∧ Meteorological_Condition(?loc, ?condmet) ∧ swrlb:equal(?condmet, "VMC") ∧ Condition_Infrastructure(?loc, ?condinf) ∧ swrlb:equal(?condinf, "OK") → Condition_Operational(?loc, "OK")
☑	Operational_Condition...	Place(?loc) ∧ Meteorological_Condition(?loc, ?condmet) ∧ swrlb:equal(?condmet, "IMC") ∧ Condition_Infrastructure(?loc, ?condinf) ∧ swrlb:equal(?condinf, "OK") → Condition_Operational(?loc, "OK")

Relationship among Ontology, Petri Network and Data Base



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Each year numerous unidentified aircrafts are observed flying over Brazilian airspace.

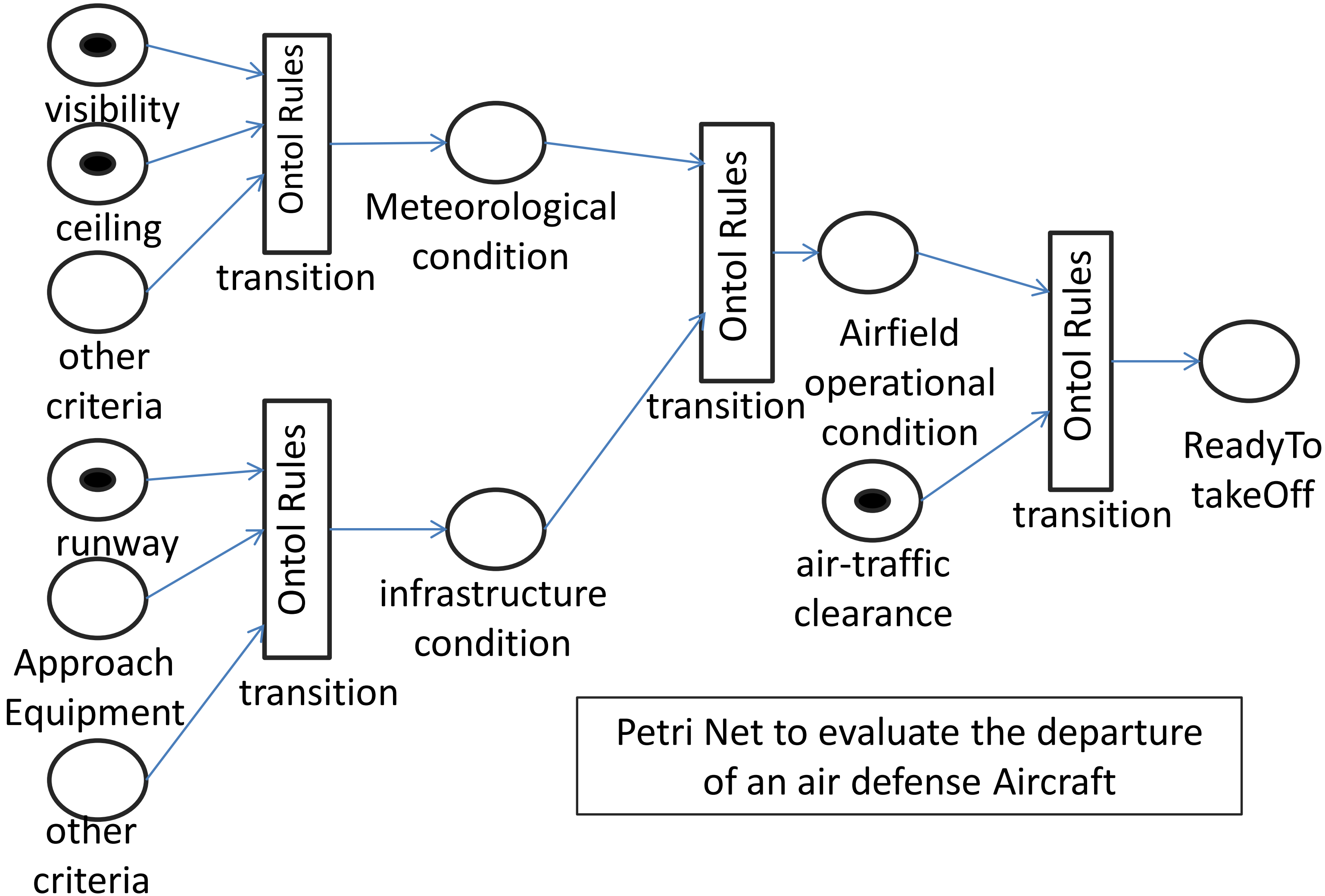
1. Air Defense should evaluate all unknown air traffic.
   - Not Threats, or
   - Involved with illicit substances.

2. Traffic that is non-identified or of concern will be subjected to enforcement of airspace policing measures by AD interceptors.

Evaluate Conditions

- meteorological conditions.
- distance from the air base.
- performance of the target.
- flight safety requirements.
- tactical and operational requirements.
- others.

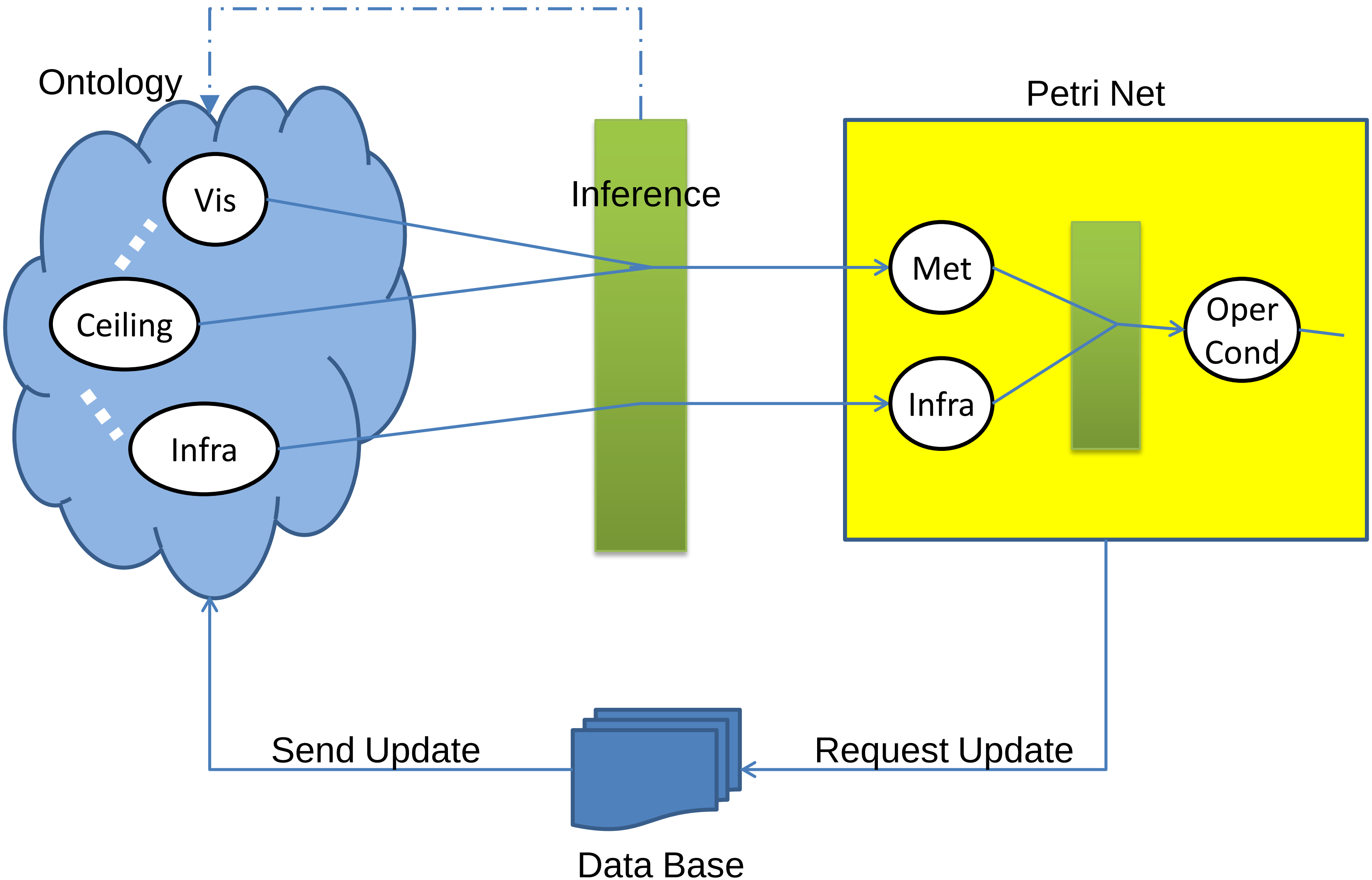
Representing air space policing measures with a segment of PN



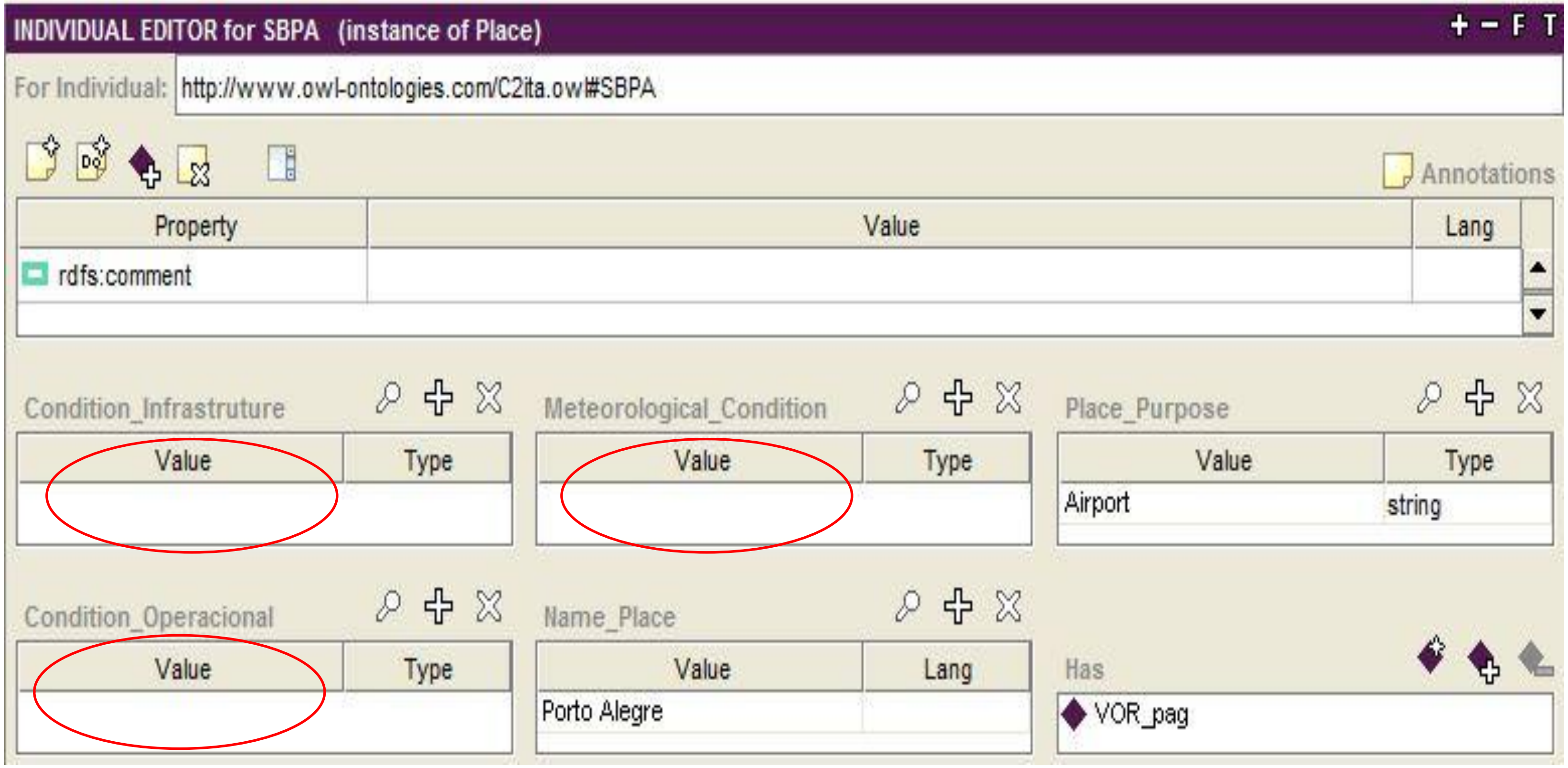
Petri Net to evaluate the departure of an air defense Aircraft

The rules, represented in the transitions, are implemented in the ontology, where the values for the individuals of the ontology refer to places in the PN.

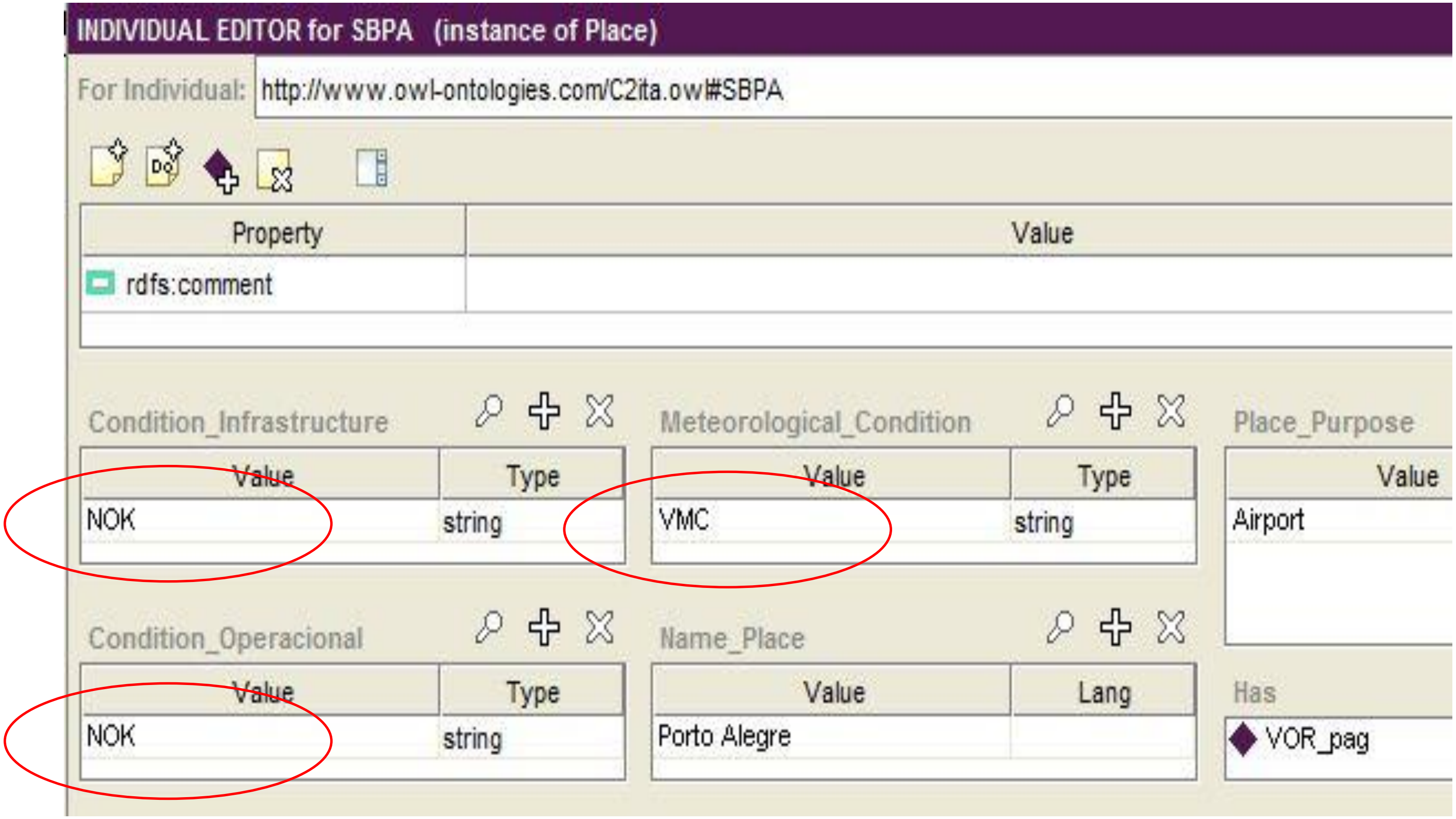
An unknown aircraft was detected by Air Traffic Control	Start the process
it was decided that an air defense aircraft should take off	Inference
procedures should rigorously be followed	Petri Net


Ontology
Vis
Ceiling
Infra
Inference
Petri Net
Met
Infra
Oper Cond
Send Update
Request Update
Data Base

The figure represents the Place "SBPA" before the rules related to Meteorological and Infrastructure Conditions be applied.



The figure represents an Individual of the ontology after the rules be applied.



ROADMAP

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- ✓ MODEL FOR SIMULATION AND ANALYSIS
- ✓ CASE STUDY: TYPICAL AIR DEFENSE SCENARIO
- ✓ <u>CONCLUSION</u>

CONCLUSION

1. The model is meant to ensure the decision maker that all pre-requisites for its decision were reviewed and judged appropriate.

2. Modeling the processes leading to a destruction shot as a PN resulted in a much more comprehensive understanding of the domain, and led to the definition of various concepts involved and their intrinsic relations, which were then used to develop the supporting ontology.

3. The PN also determines the sequencing of actions. Another feature of PN is to ensure that, with the firing of a transition, it is known that all of its pre-conditions have been observed.

4. The model is fully applicable in other operating environments that can be characterized as a decision flow, such as management of support equipment, calamities, and vehicle control.

5. For future work, the use of Colored Petri Nets will improve the decision support process.

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