COAST – An Operational Planning Tool for Course of Action Development and Analysis

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Defence Science and Technology Organisation

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Presentation Outline

- Background
- Operational Planning
- Conceptual Modelling of the Planning Domain
- Modelling of COAs
- Analysis of COAs
- Course Of Action Scheduling Tool (COAST)
- Summary and Future Work

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Background - Authors

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  - Command and Control Division
  - Defence Science and Technology Organisation
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- Guy Gallasch
  - Computer Systems Engineering Centre
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  - Department of Computer Science
  - University of Aarhus
  - Aarhus, DENMARK

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Background – Collaborative Research Partners

- Australian National University
  - Canberra, Australia
- University of Adelaide
  - Adelaide, Australia
- TTCP AG3 Dynamic Planning and Execution
  - Australian Representative, Lin Zhang (DSTO)
  - US AFRL, NRL, ARL representatives
  - UK DSTL representative
  - Canada DRDC representative

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Background – End Users

- Deployable Joint Force Headquarters, Australia
- Australian Defence Force Warfare Centre, Australia
- HQ Joint Operations Command, Australia

Operational Planning

- Strategic Objectives->End State = Set of Conditions
- Set of Conditions = Desired Effects
- Desired Effects -> Tasks
- Tasks
  - Assigned Resources
  - Synchronised with other tasks
  - Pre-Conditions
- Tasks ---…---> Lines Of Operation
- Lines Of Operation = Detailed COA

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Operational Planning - Problems

- Time Pressure
- Uncertainty
- Distributed Groups
- 100s of tasks
- COAST aims to:
  - Resolve potential conflicts in resource requirements
  - Ensure causal interdependency (Effects/Pre-Conditions)
  - Impose temporal constraints
- MS Project:
  - Pre-defined schedules of tasks
  - No analytical methods

Conceptual Modelling of the Planning Domain

- Mission
- Desired End state
- Initially valid conditions
- Available resources
- Limitations

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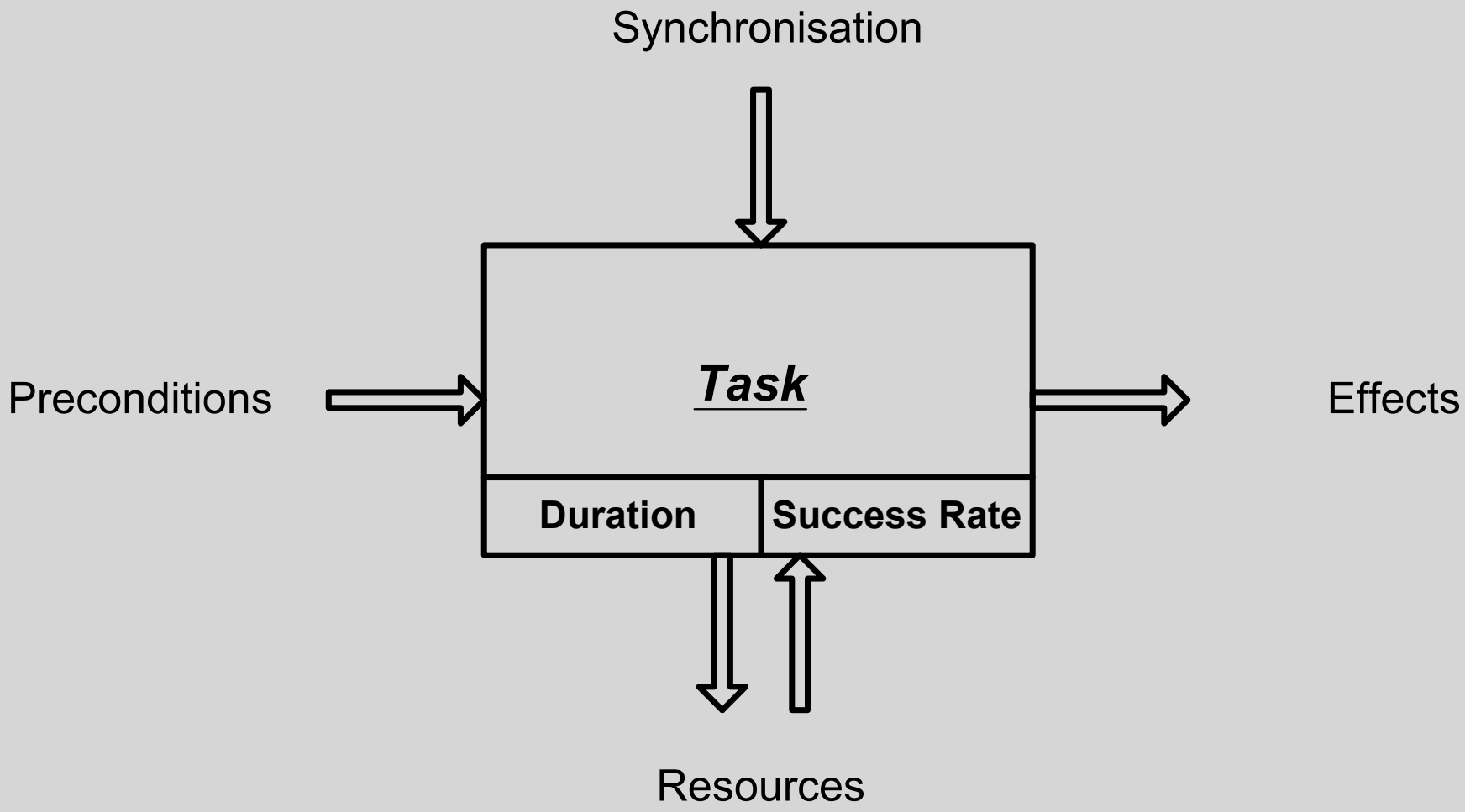
Conceptual Modelling of the Planning Domain



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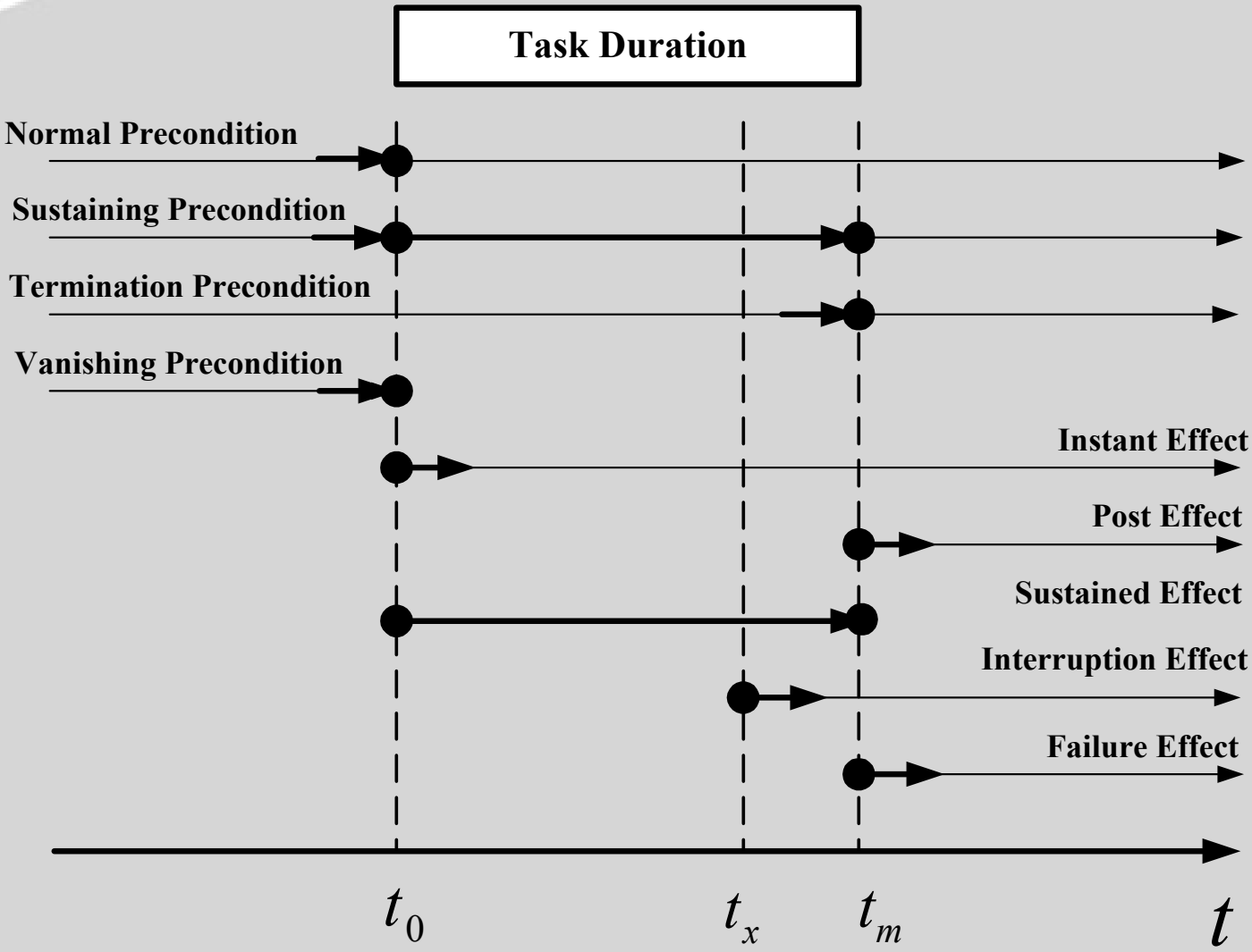
Conceptual Modelling of the Planning Domain



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Conceptual Modelling of the Planning Domain - Example

- **Mission**: Recover island from the occupation of an opposition force through amphibious operation
- **Desired End State**: Amphibious forces successfully landed
- **Initially Valid Conditions**: Fighter and AAR aircraft deployed to the AO
- **Available Resources**: A number of different Aircraft, Ships, and Troops (detail later)
- **Limitations**: Not to trespass in 3rd party airspace/waters and non favourable weather conditions

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Conceptual Modelling of the Planning Domain - Example

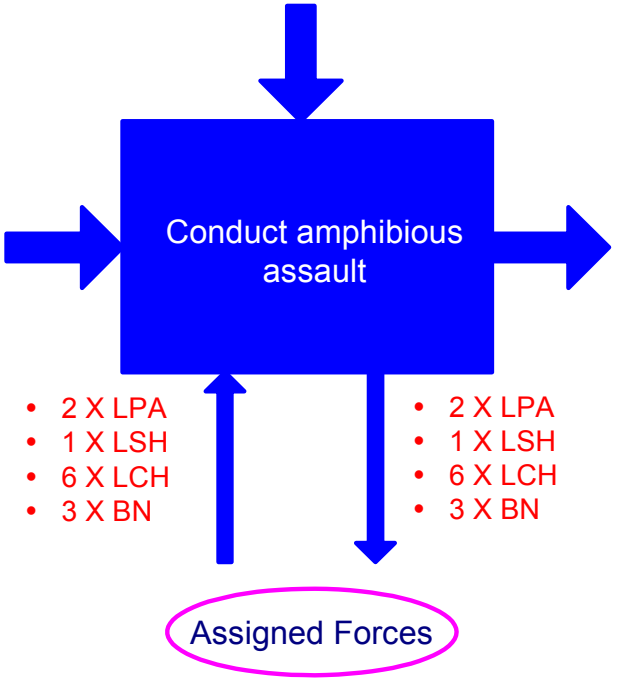
COAST: Conduct amphibious assault

Task Information

Task Duration: 4 Hours
Probability of Success 90%

Synchronisation:
- As Soon As Possible

Preconditions:
- Local air control established
- Local sea surface control established
- Local sea sub-surface control established
- En route sea mines cleared
- POE established



Effects:
- Amphibious forces succesfully landed

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Conceptual Modelling of the Planning Domain - Example

	Task name	Preconditions	Effects	Resources	Lost Res.	Duration	Sync. Info.
T1	Conduct amphibious assault	•Local air control established (SP) •Local sea surface control established (SP) •Local sea sub-surface control established (SP) •En route sea mines cleared (NP) •POE established (NP)	•Amphibious forces successfully landed (PE)	2 LPA 1 LSH 6 LCH 3 BN		4 Hours	As Soon As Possible
T2	Conduct combat air patrol	•FOB established (NP) •Fighter aircraft deployed to the AO (NP) •En route refueling provided (SP)	•Local air control established (SE)	12 FA 18		As required	
T3	Conduct ASW operations in the AO	•FOB established (NP) •Local air control established (SP)	•Local sea sub-surface control established (SE)	2 MPA		As required	
T4	Conduct airborne operations	•Local air control established (SP) •FOB established (NP) •FARP established (NP)	•POE established (PE)	12 Blackhawk 2 ABN BN	2 Blackhawk	8 Hours	
T5	Conduct maritime escort operation	•Local air control established (SP)	•Local sea surface control established (SE)	4 FFH		As required	
T6	Conduct mine clearance operation	•Local air control established (SP) •Local sea surface control established (SP) •Local sea sub-surface control established (SP)	•En route sea mines cleared (PE)	•4 Mine Hunters		48 Hours	
T7	Establish FOB		•FOB established (PE)	•1 ECSS		60 Hours	
T8	Establish FARP		•FARP established (PE)	•1 Eng Coy		40 Hours	
T9	Provide AAR	•FOB established (NP) •AAR aircraft deployed to the AO (NP)	•En route refueling provided (SE)	•4 AAR		As required	

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Modelling and Analysis of COAs

- Using Coloured Petri Nets
  - Discrete Event System with formal mathematical semantics and rigorous analysis capabilities
- Why Coloured Petri Nets?
  - Concurrent systems
  - Resource allocation
  - State based system
  - Generation of possible events from any given state
  - Event Duration and System Time
  - Formal mathematical modelling language
  - Analysis capabilities through state space analysis

Modelling and Analysis of COAs

- The CPN model formally captures the execution of COA:
  - Tasks and their attributes (pre-conditions, effects, duration, required resources)
  - Set of currently valid conditions
  - Available resources
- The state of the system is represented by:
  - Set of tasks (idle, executing, or done)
  - Set of currently valid conditions
  - Set of currently available resources
- An event in the system could be:
  - Start/Termination of Tasks
  - Change of valid conditions
  - Change of available resources

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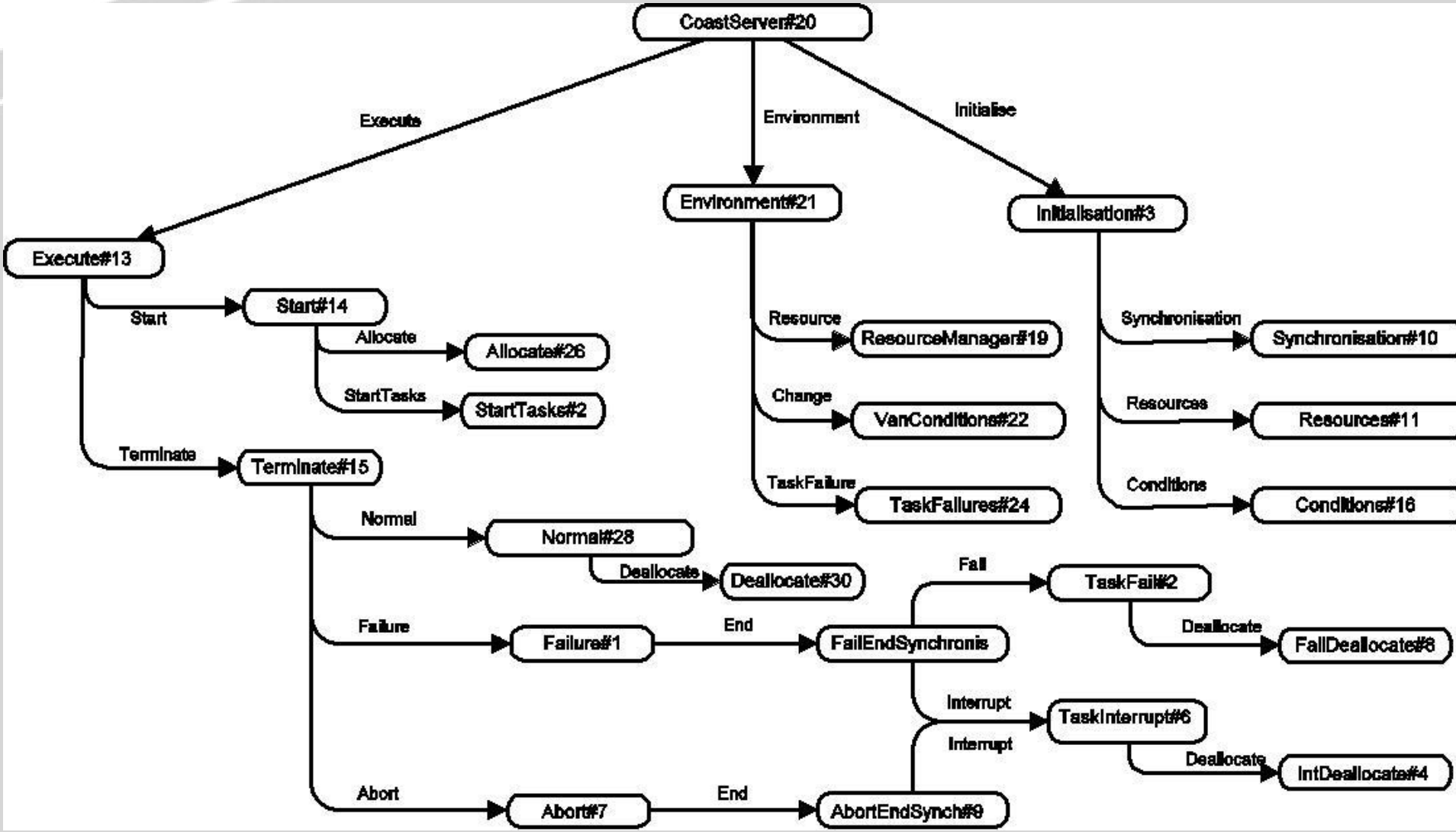
Modelling and Analysis of COAs



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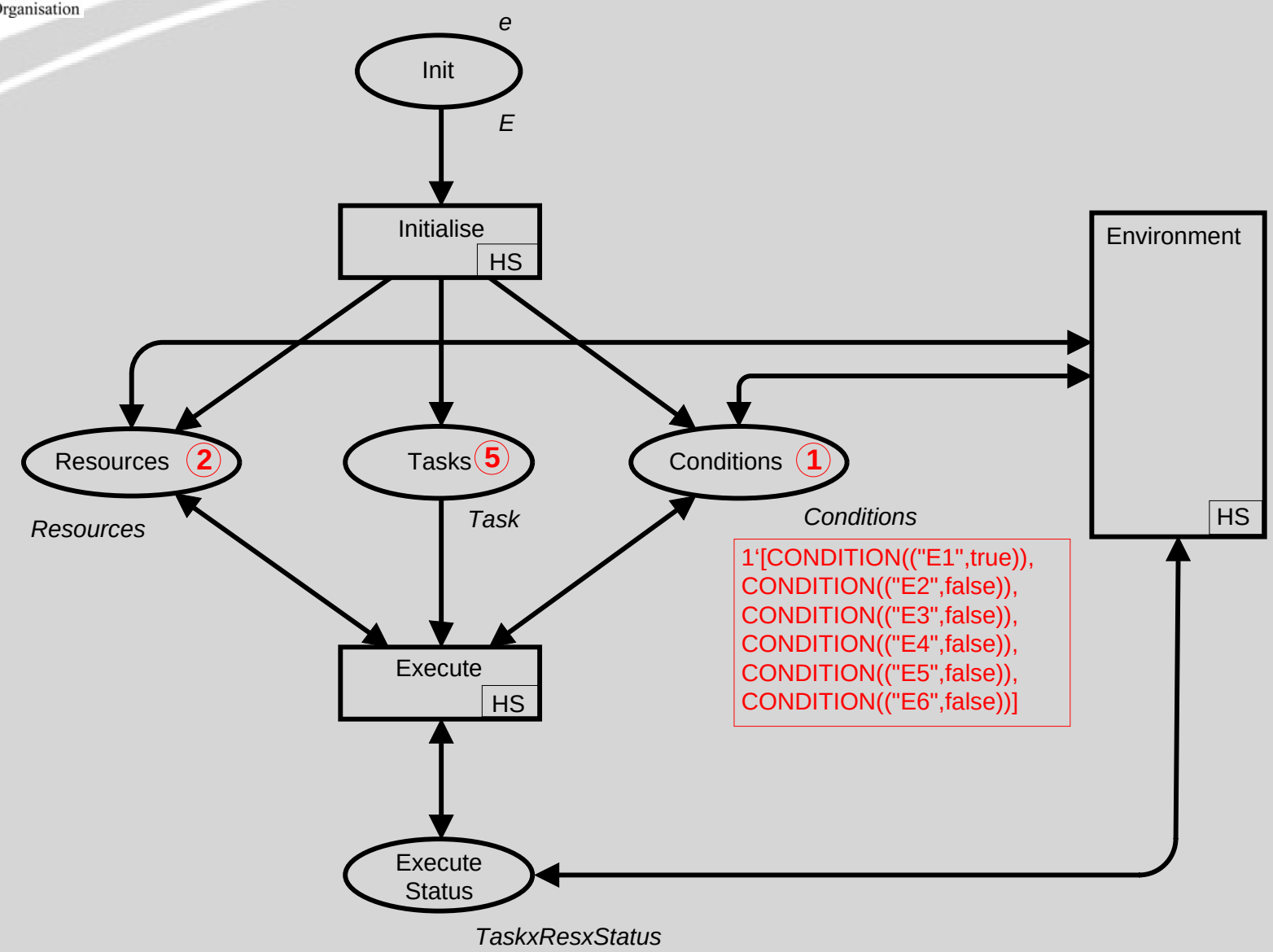
Modelling and Analysis of COAs



Modelling and Analysis of COAs

- CPN model ensures the line of operation is suitable (logical) and feasible (resource conflicts)
- Input: Set of tasks, Initially Valid Conditions, Available Resources
- Output: Lines of operation (start and end times for all tasks leading to the end state)
- Method: State Space Analysis of the CPN model

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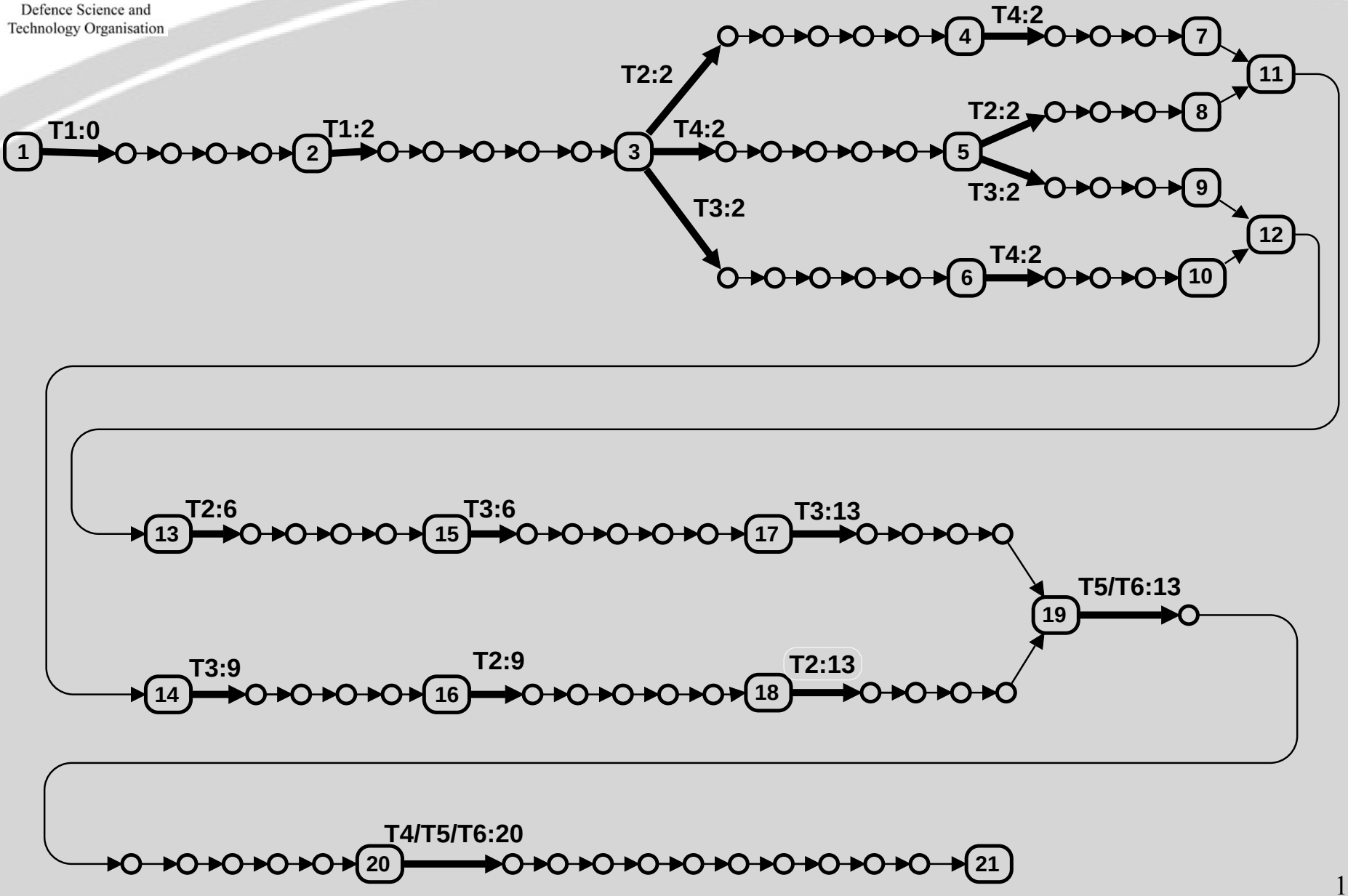
Modelling and Analysis of COAs



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Modelling and Analysis of COAs

- 2 phases of LOP generation
  - Depth-first
  - Breadth-first

COAST Overview

- COAST – Coast Of Action Scheduling Tool
- COA Development and Analysis
- Task scheduling must be suitable (logical) and feasible (resources)
- Client-Server Architecture

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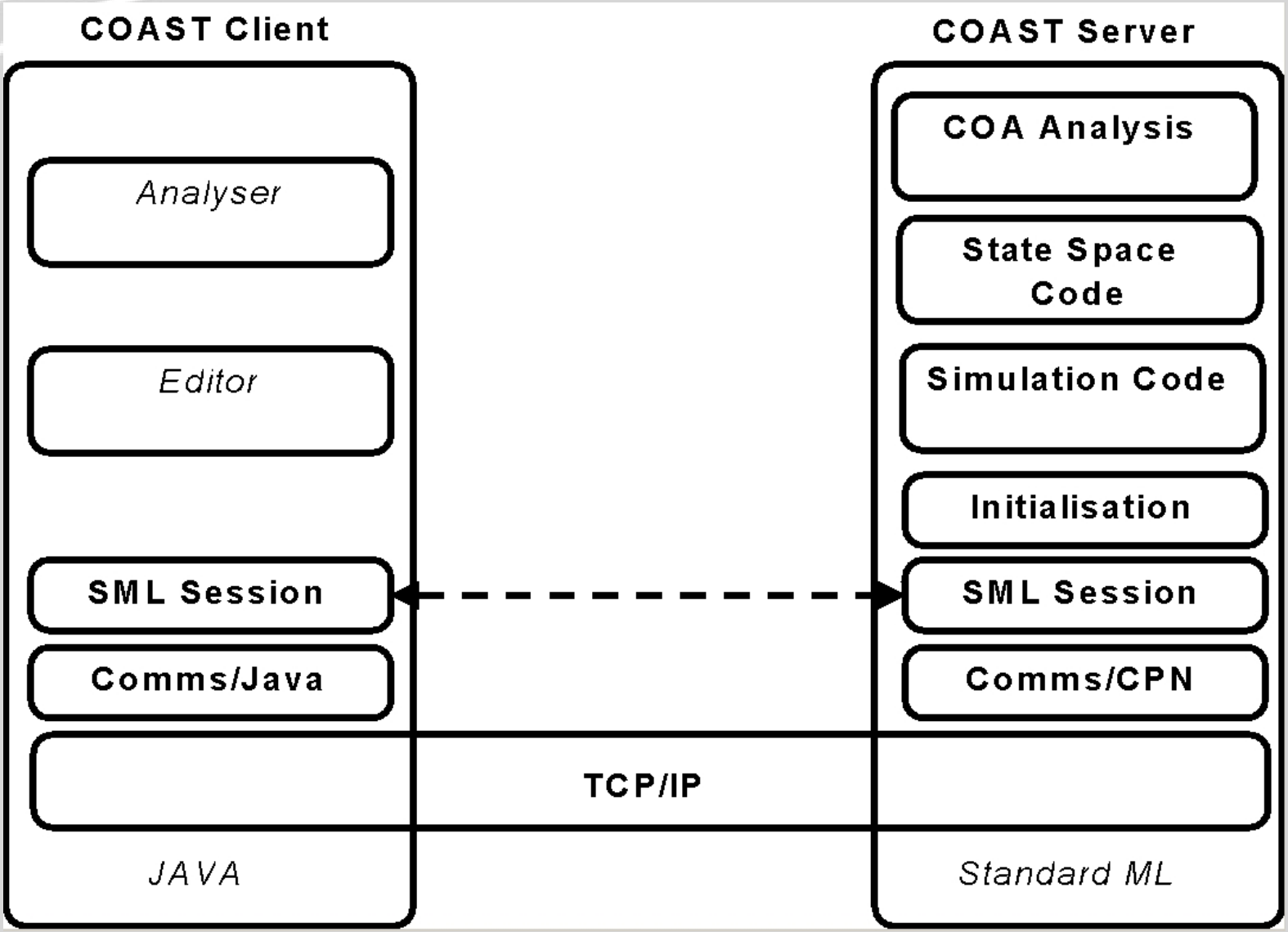
Course Of Action Scheduling Tool (COAST)



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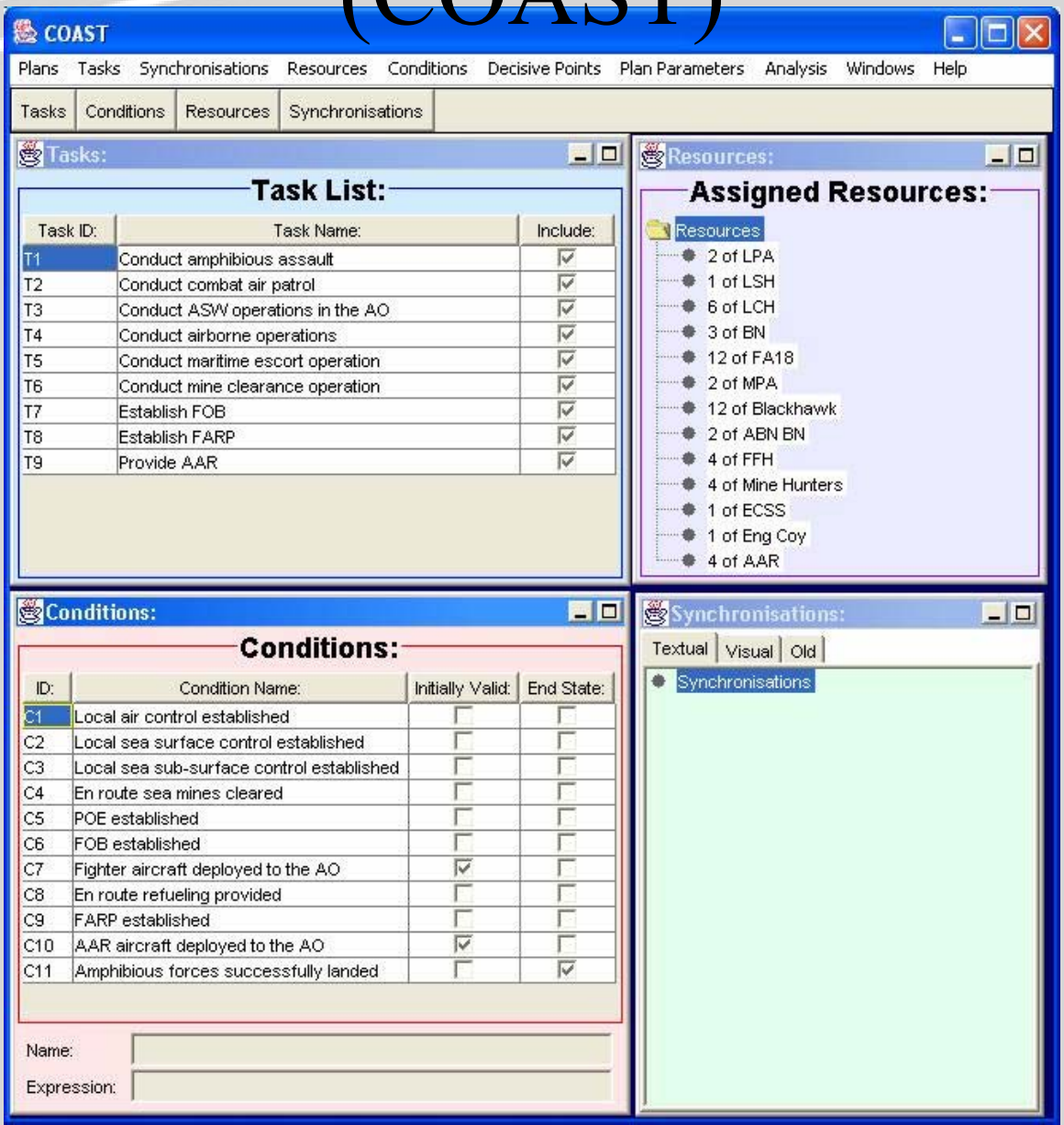

Course Of Action Scheduling Tool

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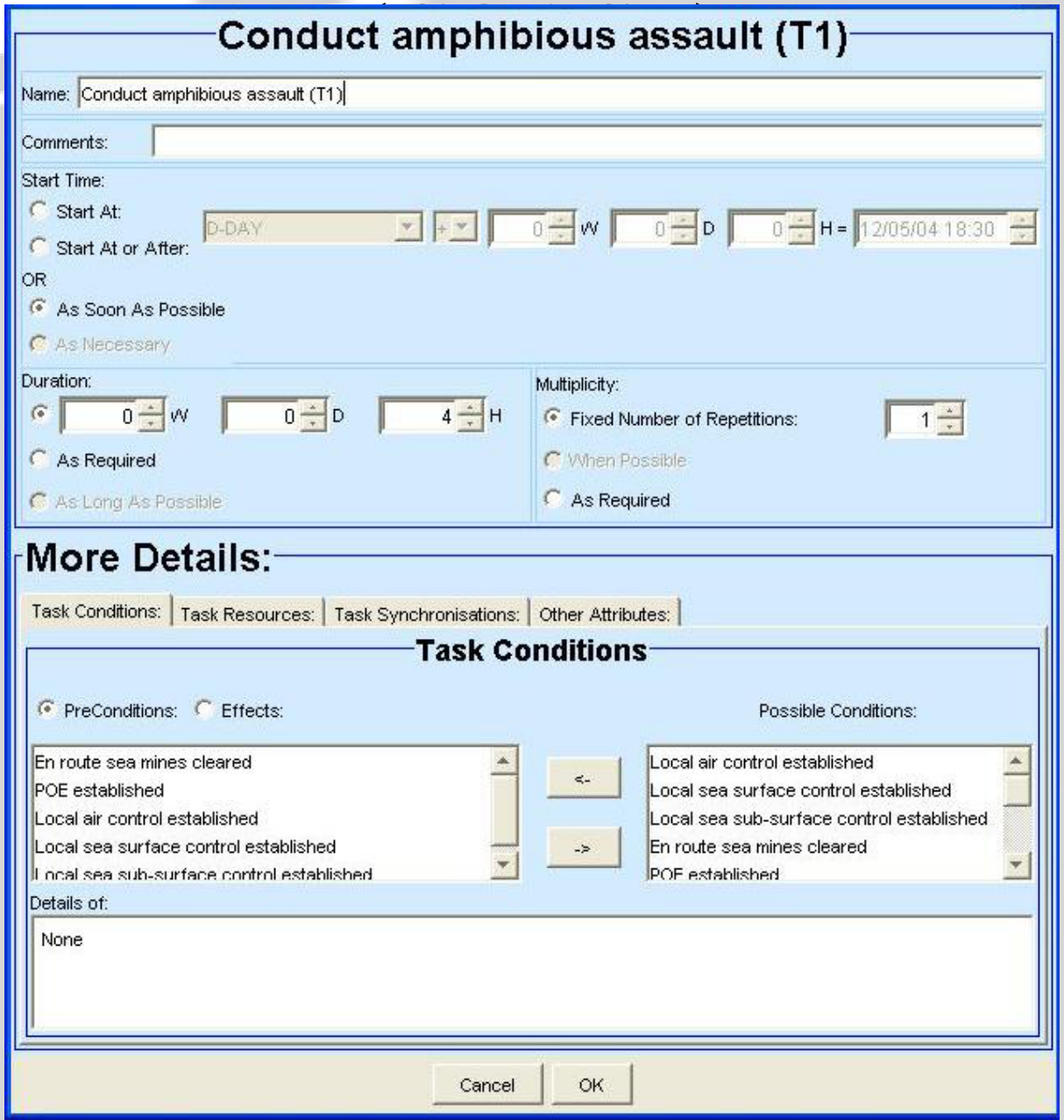

Course Of Action Scheduling Tool (COAST)

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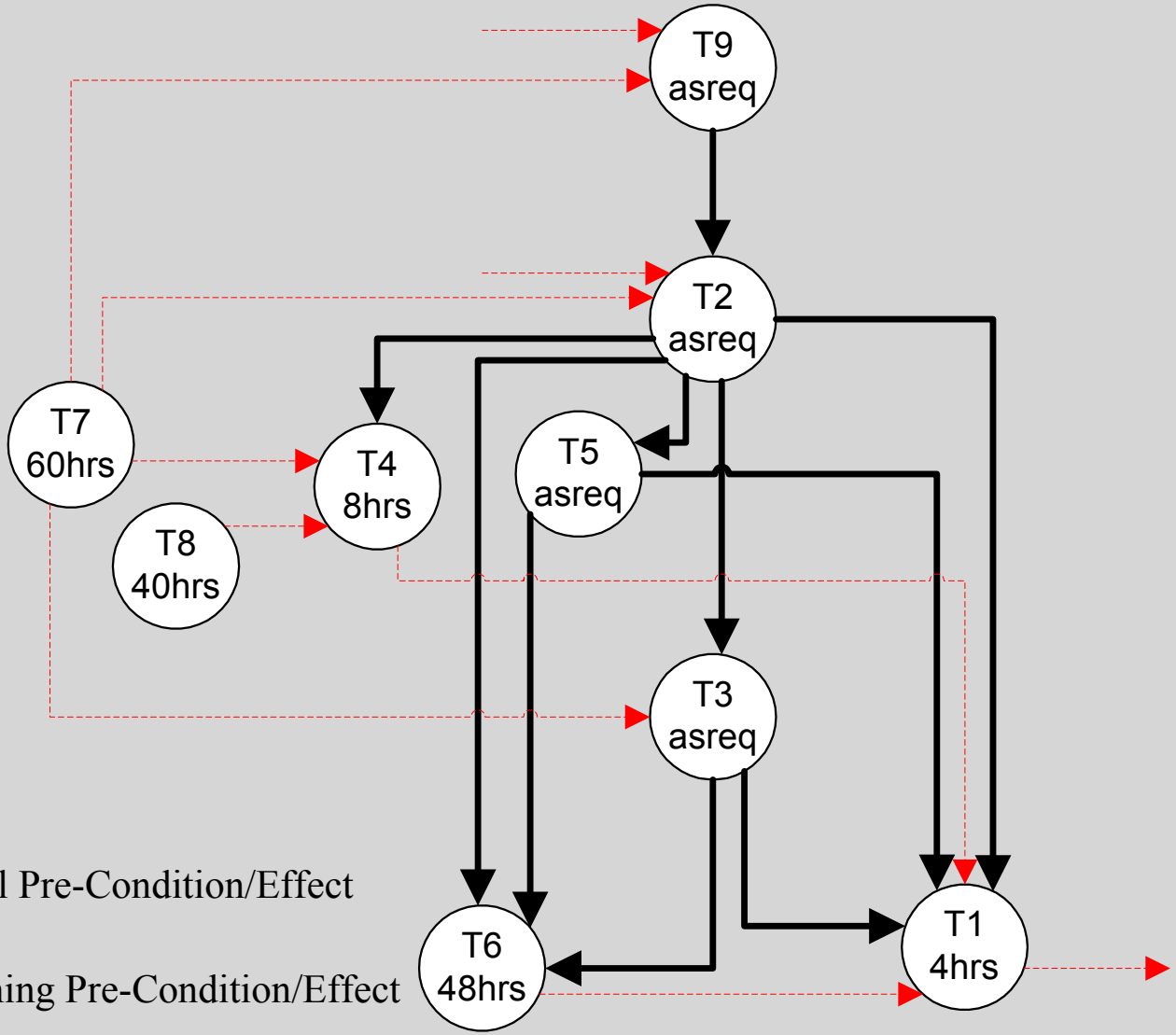

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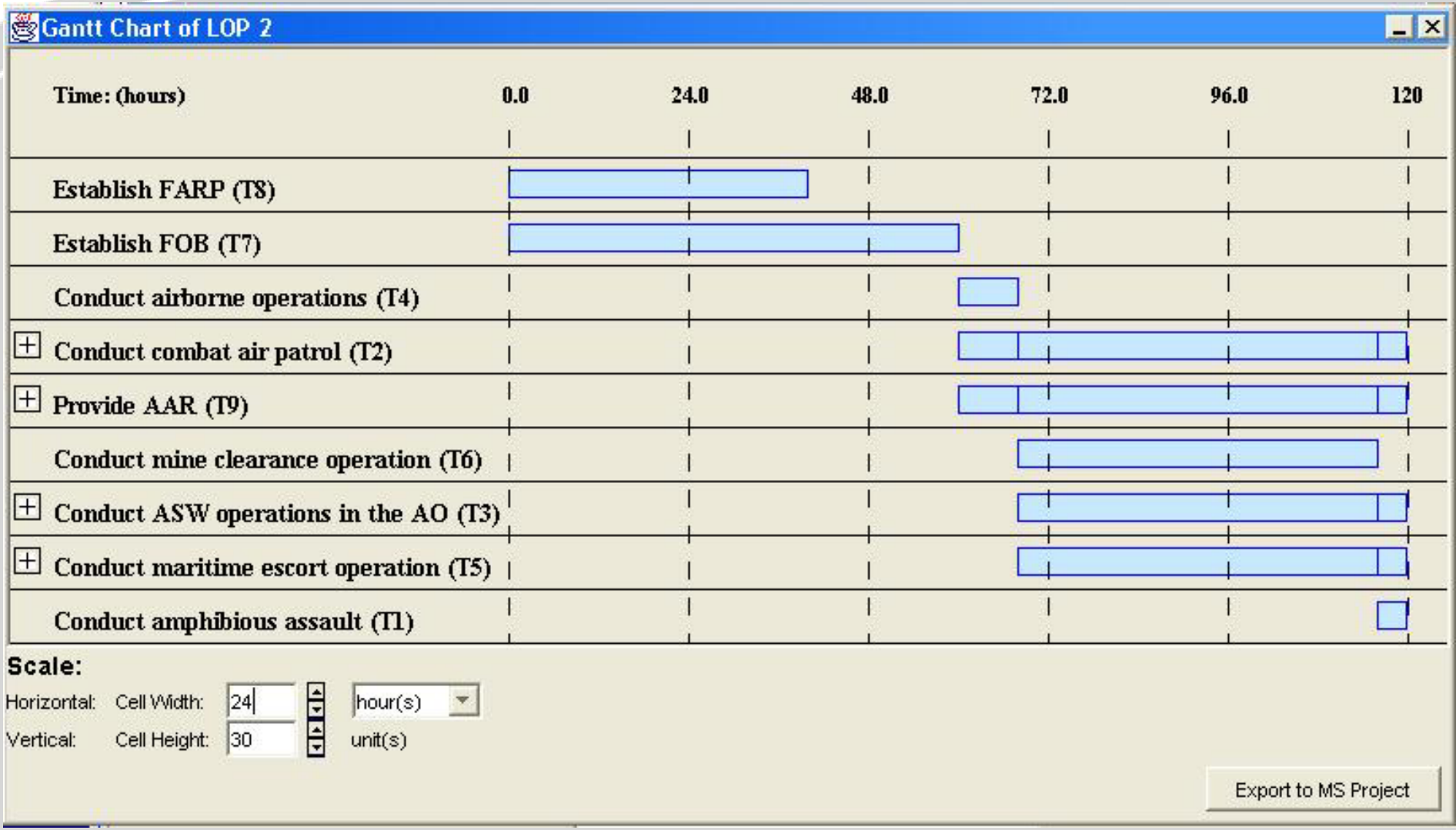
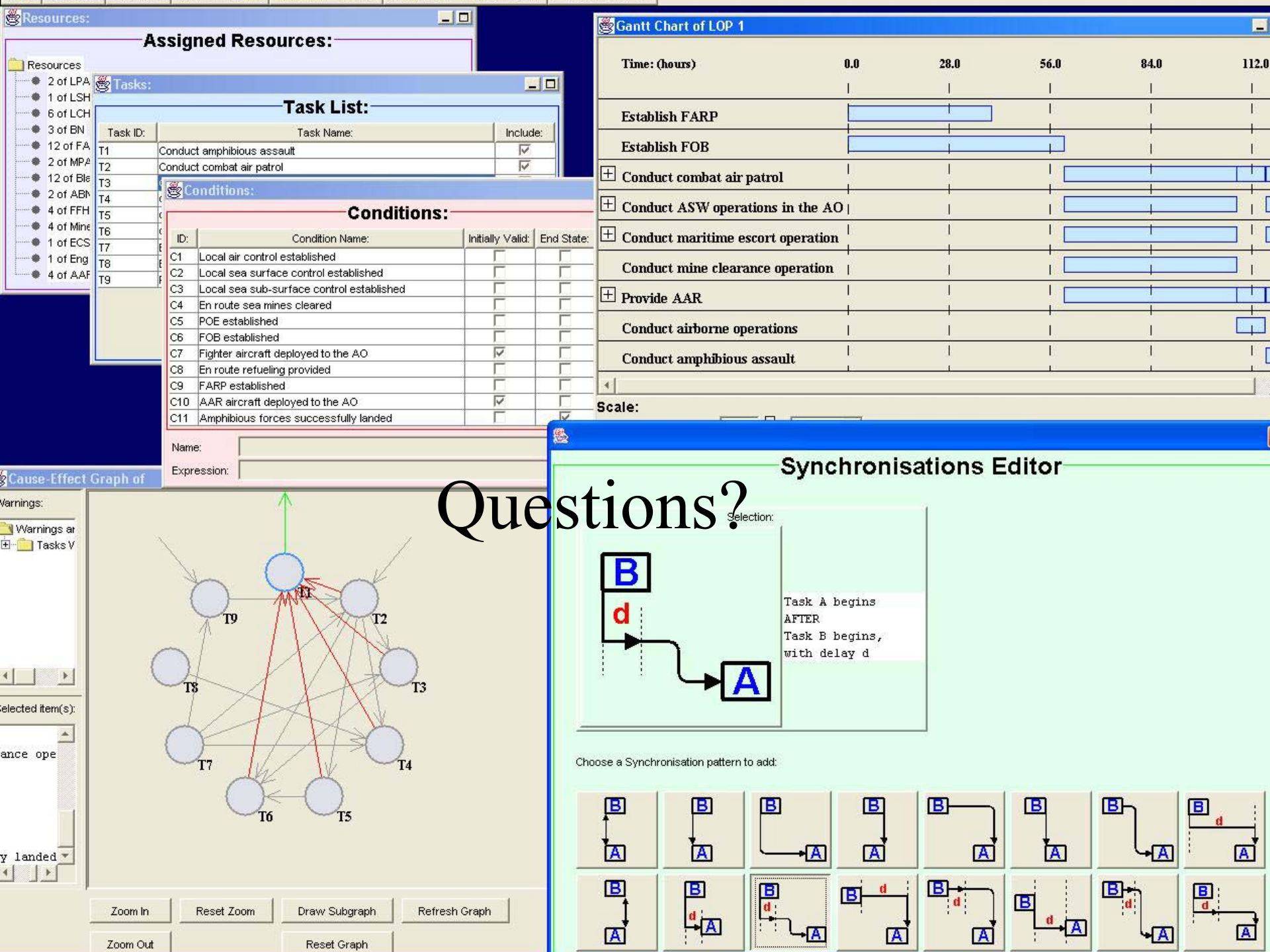


Summary

- Formal representation of the planning domain
- Modelling and Analysis using Coloured Petri Nets
- Prototype tool with client/server architecture
- COAST client captures the planning problem (INPUT)
- COAST server returns suitable and feasible LOPs (OUTPUT)

Current and Future Work

- Tool experimentation
- Multiple Servers
- Extension of features in current client and server


Resources:
Assigned Resources:
Resources
2 of LPA
1 of LSH
6 of LCH
3 of BN
12 of FA
2 of MPA
12 of Ble
2 of ABN
4 of FFH
4 of Mine
1 of ECS
1 of Eng
4 of AAF
Tasks:
Task List:
Task ID:
Task Name:
Include:
T1 Conduct amphibious assault
T2 Conduct combat air patrol
Conditions:
Conditions:
ID:
Condition Name:
Initially Valid:
End State:
C1 Local air control established
C2 Local sea surface control established
C3 Local sea sub-surface control established
C4 En route sea mines cleared
C5 POE established
C6 FOB established
C7 Fighter aircraft deployed to the AO
C8 En route refueling provided
C9 FARP established
C10 AAR aircraft deployed to the AO
C11 Amphibious forces successfully landed
Name:
Expression:
Gantt Chart of LOP 1
Time: (hours)
0.0
28.0
56.0
84.0
112.0
Establish FARP
Establish FOB
Conduct combat air patrol
Conduct ASW operations in the AO
Conduct maritime escort operation
Conduct mine clearance operation
Provide AAR
Conduct airborne operations
Conduct amphibious assault
Scale:
Cause-Effect Graph of
Warnings:
Warnings ar
Tasks V
Selected item(s):
ance ope
y landed
T1
T2
T3
T4
T5
T6
T7
T8
T9
Zoom In
Reset Zoom
Draw Subgraph
Refresh Graph
Zoom Out
Reset Graph
Synchronisations Editor
Selection:
B
d
A
Task A begins
AFTER
Task B begins,
with delay d
Choose a Synchronisation pattern to add:

Questions?