International Technology Alliance
In Network & Information Sciences

Hybrid Rationale and Controlled Natural Language for Shared Understanding

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MINISTRY OF DEFENCE

- Motivation

- What is rationale

- Military example

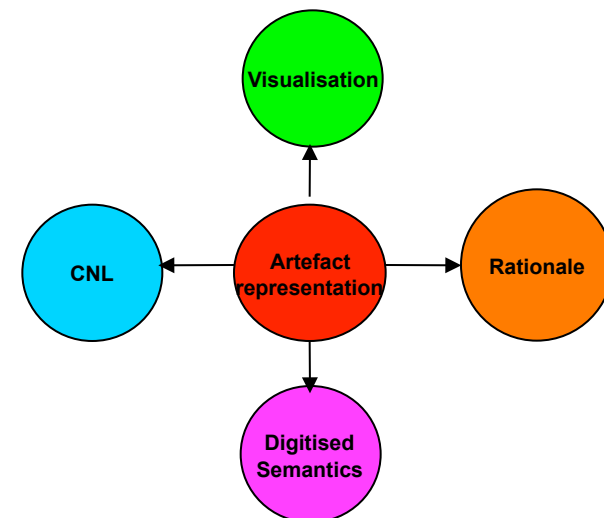- Some principles for automation

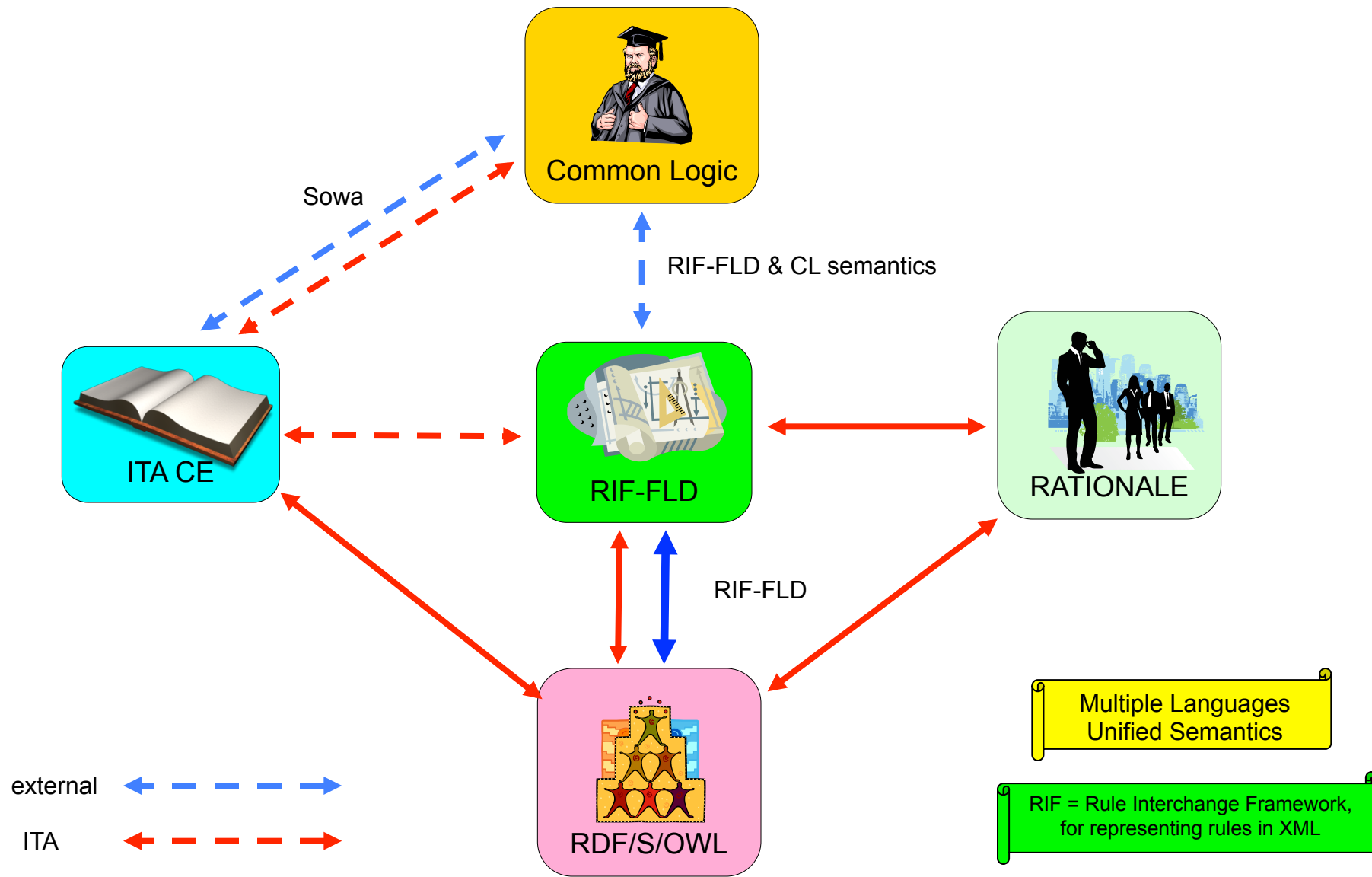- Military application

Motivation

- How do we assist people to create and use applications that reason?
  - Modelling Concepts and Writing Rules
  - Grasping the basic logic of the model and rules
  - Understanding the reasoning performed by others
  - Sharing understanding across the human team
  - Sharing reasoning across different systems

- **Representation**
    - rich expression of problems and their solutions
    - structure and logical relations/rules
    - based on generic, re-useable domain concepts
    - formal, unambiguous, semantics
- **Rationale** for <u>challenging and explanation of reasoning</u>, intent, assumptions
- **Layers of Controlled Natural Languages** for communication and <u>shared understanding</u>
- **Visualisation** for exploration of solutions and enhancing <u>human understanding of logic</u>
- **Semantic representation** for machine processing and formal definition of logical relations

Visualisation

CNL — Artefact representation — Rationale

Digitised Semantics

Common Logic

Sowa

RIF-FLD & CL semantics

ITA CE

RIF-FLD

RATIONALE

RIF-FLD

RDF/S/OWL

Multiple Languages
Unified Semantics

external

ITA

RIF = Rule Interchange Framework,
for representing rules in XML

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# Rationale – what we know so far

- **A network of reasoning steps leading from premises and assumptions to conclusions**
  - Automated, based on the logic in the ontology
  - Human, logical or intuitive

- **The record of how a person, potentially assisted by automation, reached a conclusion**

- **Patterns of reasoning, including challenges and counter challenges, leading to positive and negative support for a conclusion**

Support links for P and not P are separate

True support

False support

inconsistent

P

NOT P
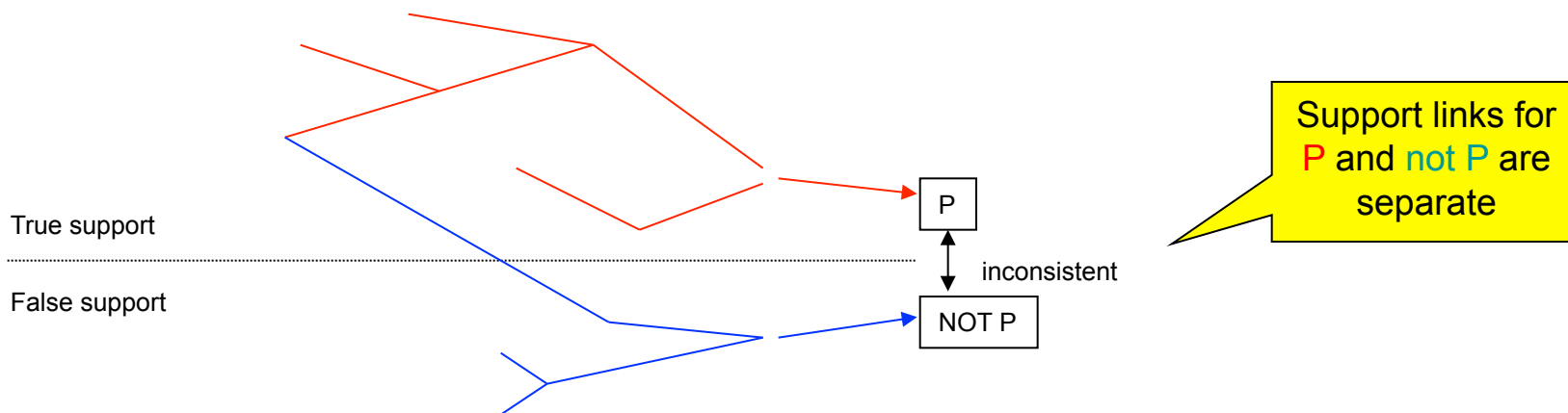
- **Visualise positive and negative support**
  - Sources, reasoning steps, assumptions
- **Propagate truth and falsity (and certainty)**
- **Determine effects of assumptions**
  - What depends on an assumption
  - What happens if an assumption is revoked
  - What assumptions are incompatible
- **Supports defeasible reasoning**

- Land Warfare School exercise
  - Rationale is a strong part of preparing and presenting a plan
- CPM evaluation
  - "Stream of Rationale" is ever-present and easily accessible
- Pathfinder 2
  - Rationale should be a hybrid of human and machine
  - Rationale may be structured or unstructured
  - Challenge/response may lead to exploration of rationale
  - Requirement to explore rationale may help to "make analysts more curious"
- We believe rationale is important in collaborative reasoning
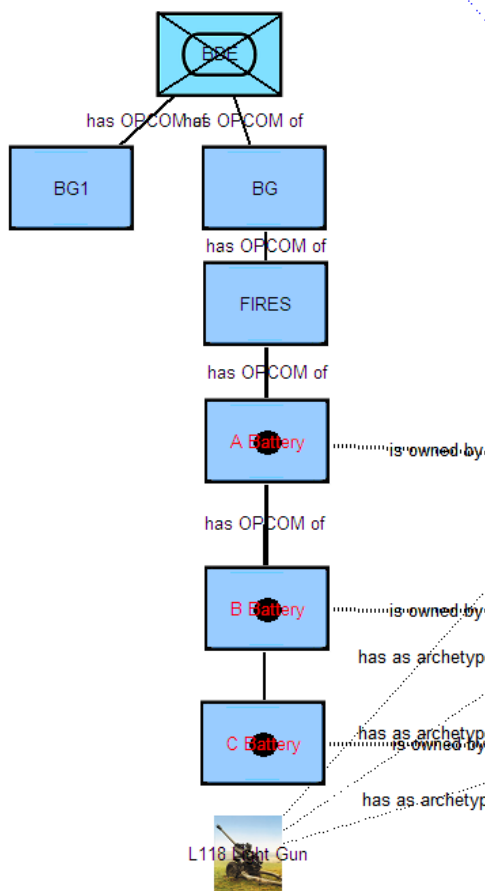
Military Example
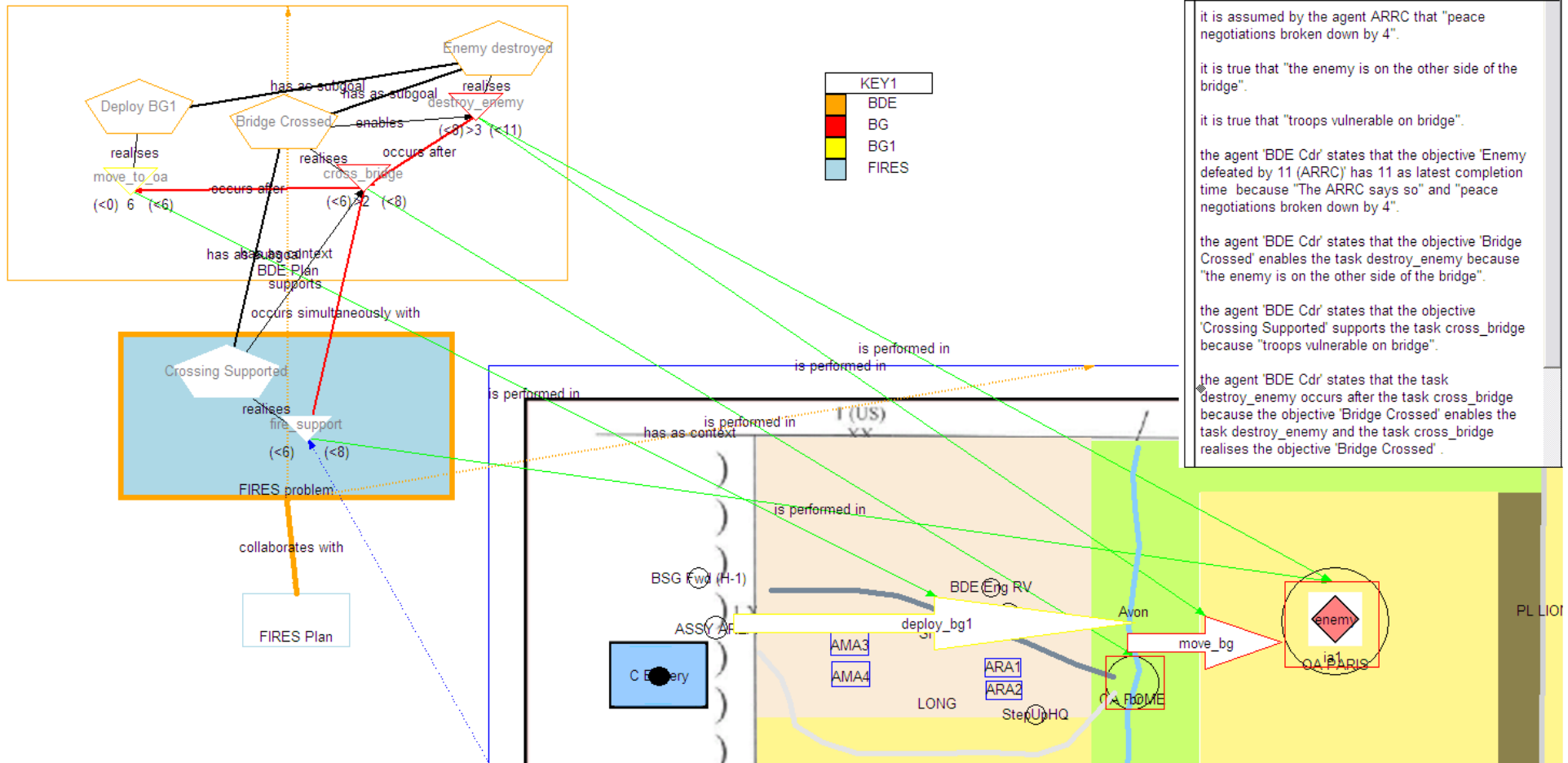
- Battle group **BG** is attacking enemy after crossing bridge
- **FIRES** must provide fire support for this crossing between 6-8
- Battle group **BG1** deployed at the same time
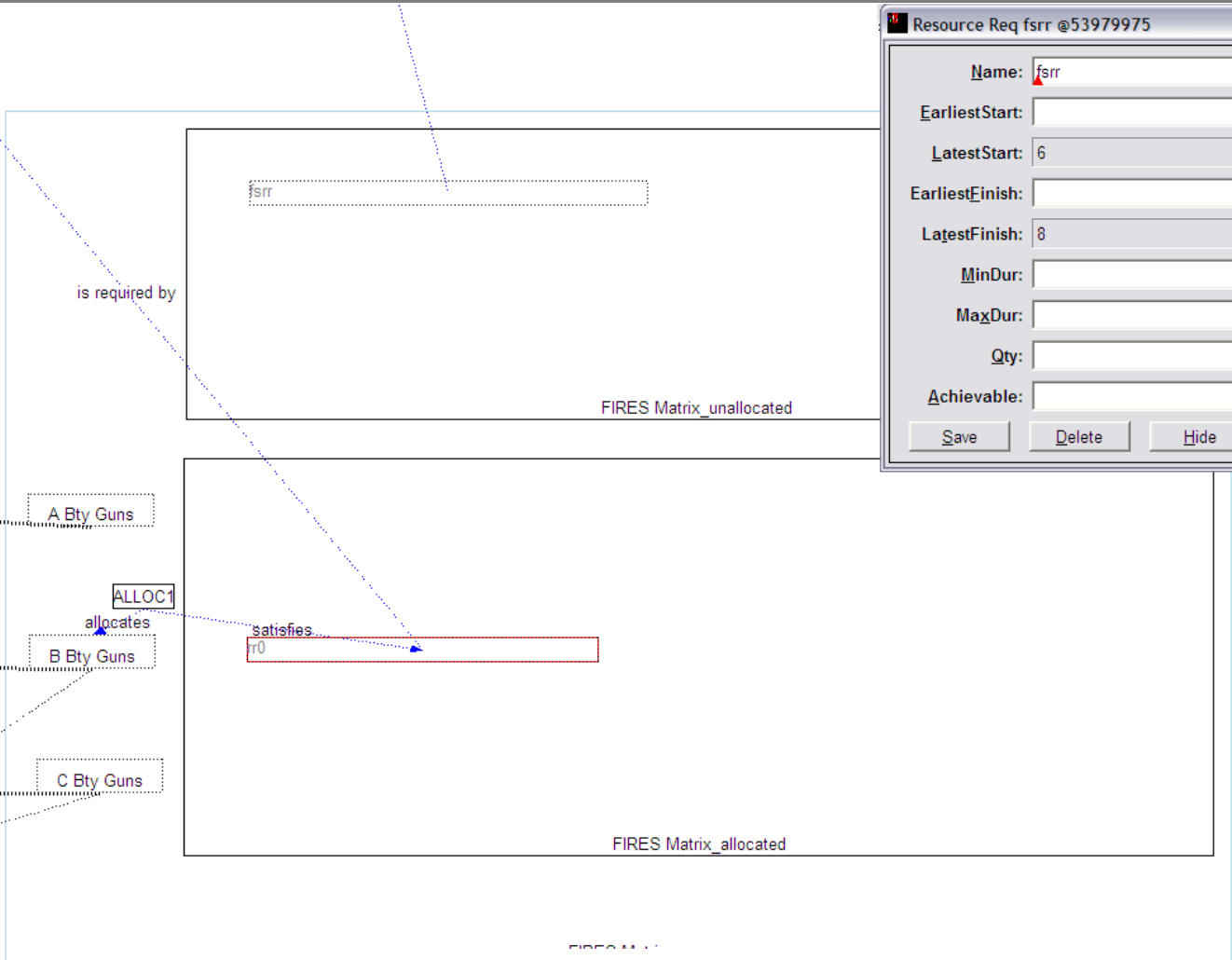- Assuming "peace negotiations broken down by 4"

Advance to OA Rome
0   7   7

has OPCOM has OPCOM of

BG1

BG

has OPCOM of

FIRES

has OPCOM of

A Battery   is owned by   A Bty Guns

has OPCOM of

ALLOC1
allocates

B Battery   is owned by   B Bty Guns

has as archetype

C Battery   has as archetype   C Bty Guns
                is owned by

has as archetype

L118 Light Gun

FIRES Resources

Resource Req fsrr @53979975

Name:	fsrr
EarliestStart:	
LatestStart:	6
EarliestFinish:	
LatestFinish:	8
MinDur:	
MaxDur:	
Qty:	
Achievable:	

Save   Delete   Hide

fsrr

is required by

FIRES Matrix_unallocated

satisfies
rr0

FIRES Matrix_allocated
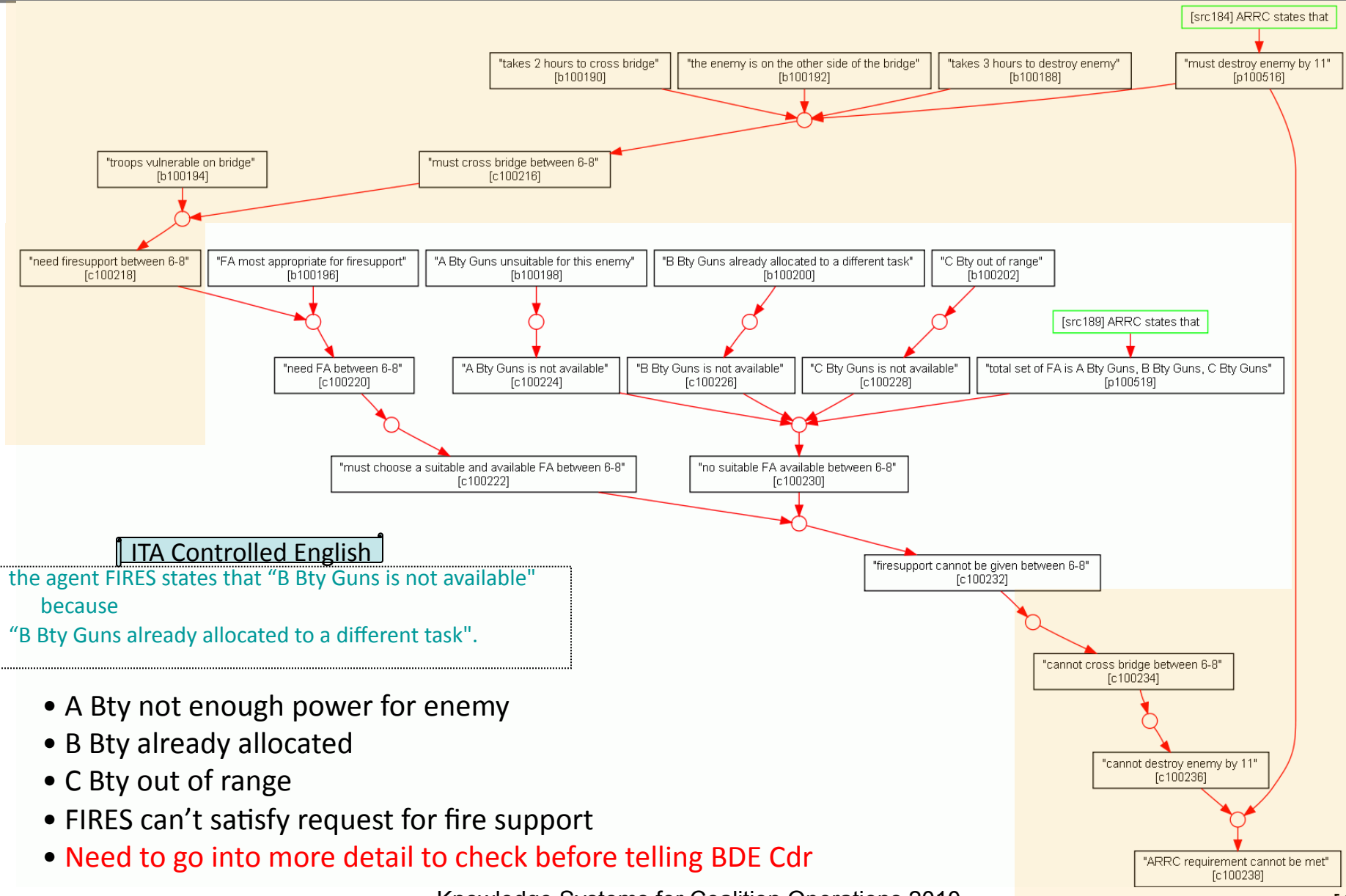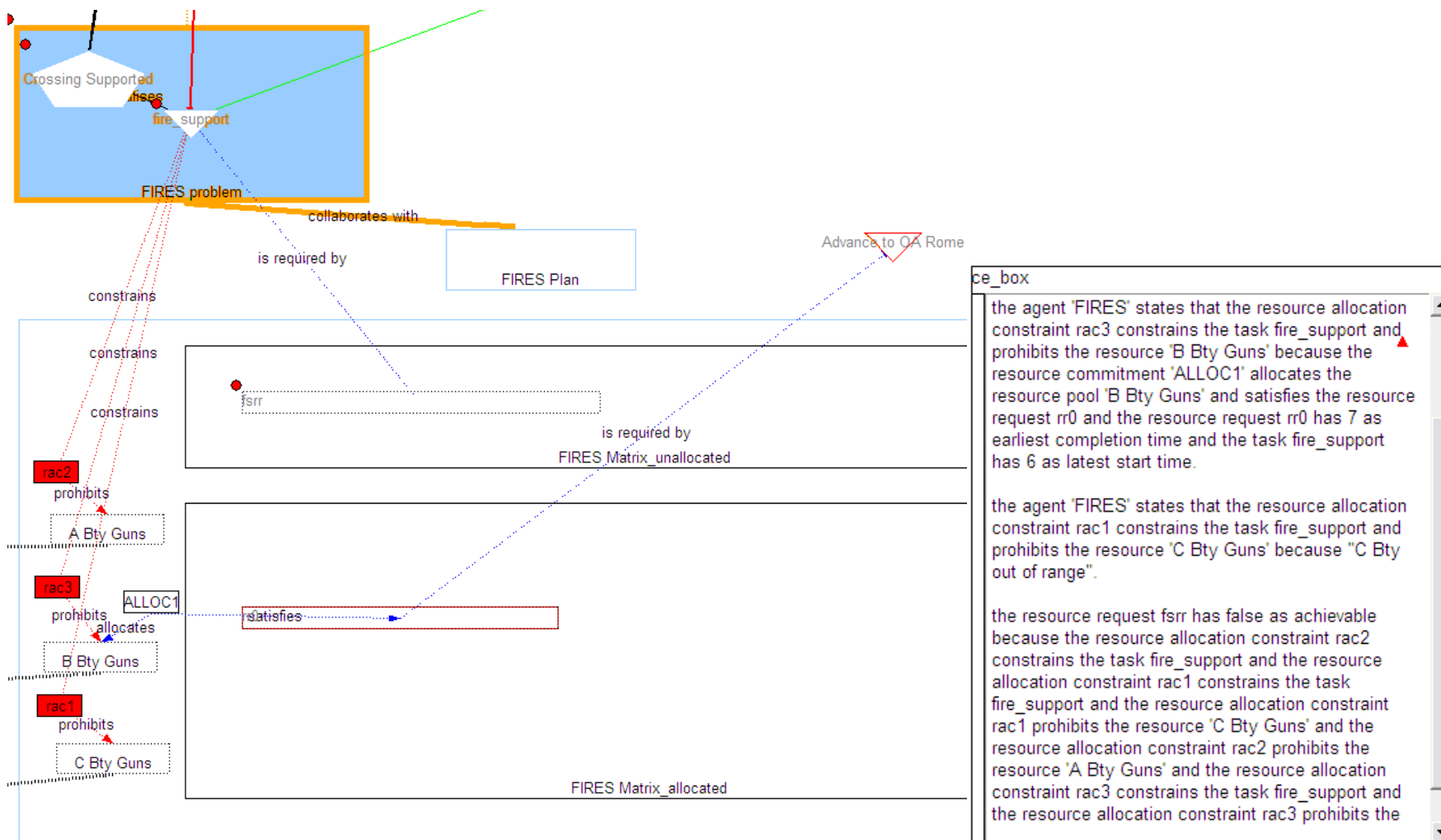
- 3 Batteries of Light Guns, A Bty, B Bty, C Bty
- A Bty reduced in power
- B Bty already allocated to another task
- C Bty a long way from the operational area

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[src184] ARRC states that

"takes 2 hours to cross bridge" [b100190]

"the enemy is on the other side of the bridge" [b100192]

"takes 3 hours to destroy enemy" [b100188]

"must destroy enemy by 11" [p100516]

"troops vulnerable on bridge" [b100194]

"must cross bridge between 6-8" [c100216]

"need firesupport between 6-8" [c100218]

"FA most appropriate for firesupport" [b100196]

"A Bty Guns unsuitable for this enemy" [b100198]

"B Bty Guns already allocated to a different task" [b100200]

"C Bty out of range" [b100202]

[src189] ARRC states that

"need FA between 6-8" [c100220]

"A Bty Guns is not available" [c100224]

"B Bty Guns is not available" [c100226]

"C Bty Guns is not available" [c100228]

"total set of FA is A Bty Guns, B Bty Guns, C Bty Guns" [p100519]

"must choose a suitable and available FA between 6-8" [c100222]

"no suitable FA available between 6-8" [c100230]

ITA Controlled English

the agent FIRES states that "B Bty Guns is not available" because
"B Bty Guns already allocated to a different task".

"firesupport cannot be given between 6-8" [c100232]

"cannot cross bridge between 6-8" [c100234]

"cannot destroy enemy by 11" [c100236]

"ARRC requirement cannot be met" [c100238]

- A Bty not enough power for enemy
- B Bty already allocated
- C Bty out of range
- FIRES can't satisfy request for fire support
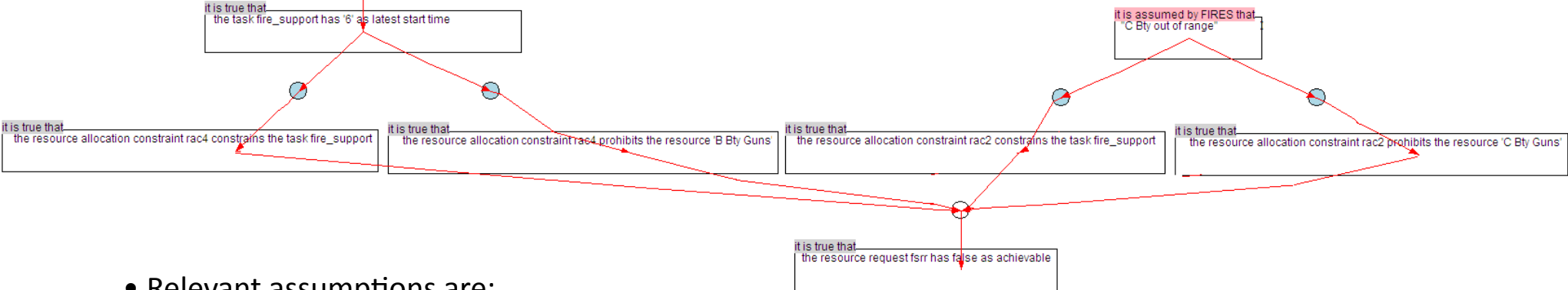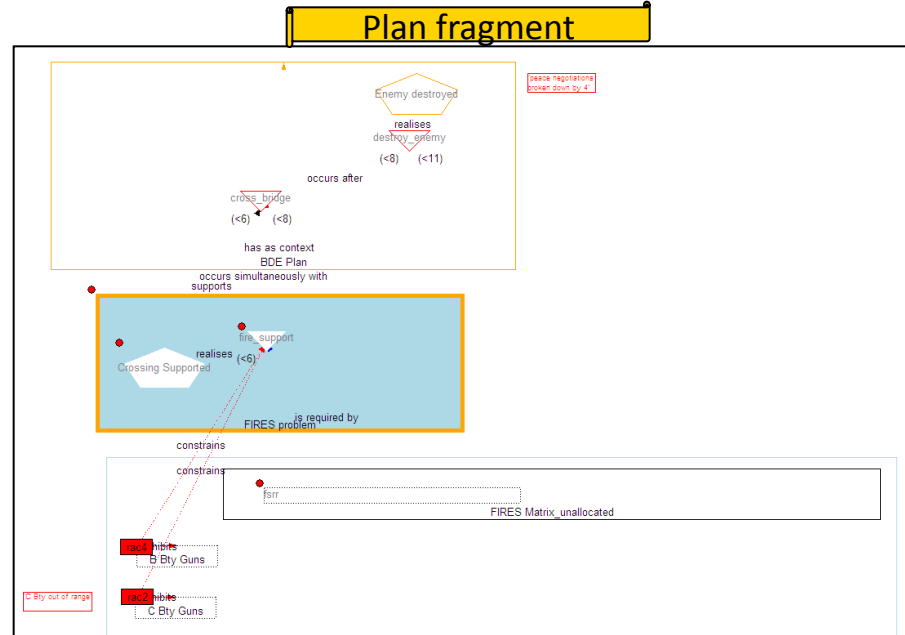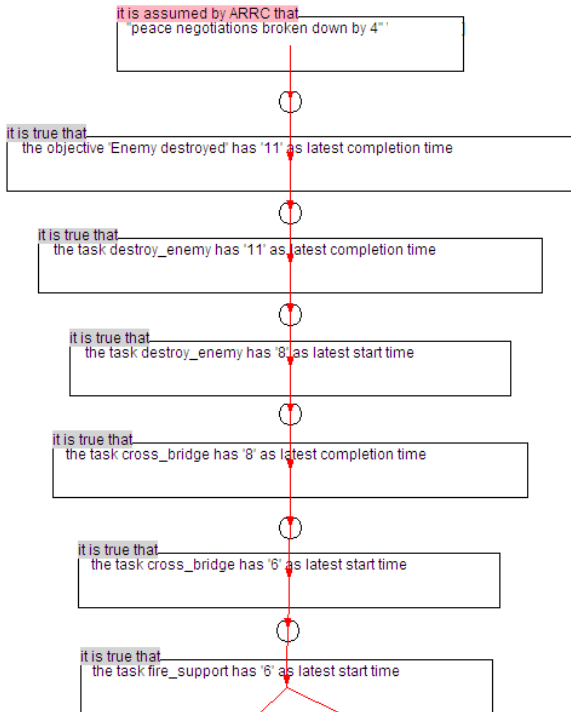- Need to go into more detail to check before telling BDE Cdr

- Adding resource allocation constraints via GUI autogenerates rationale
- ALL Bty Guns are prohibited for fire support request
- FIRES problem is reasoned to be unachievable (red dots)

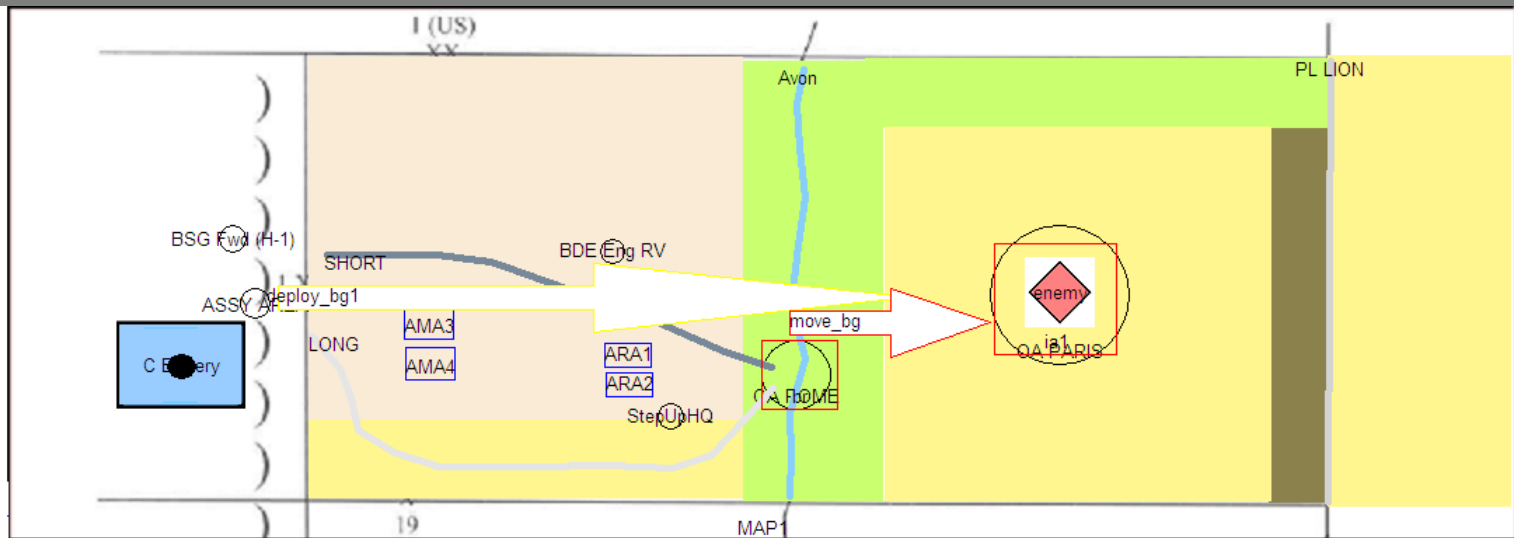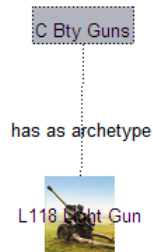Knowledge Systems for Coalition Operations 2010

[15]
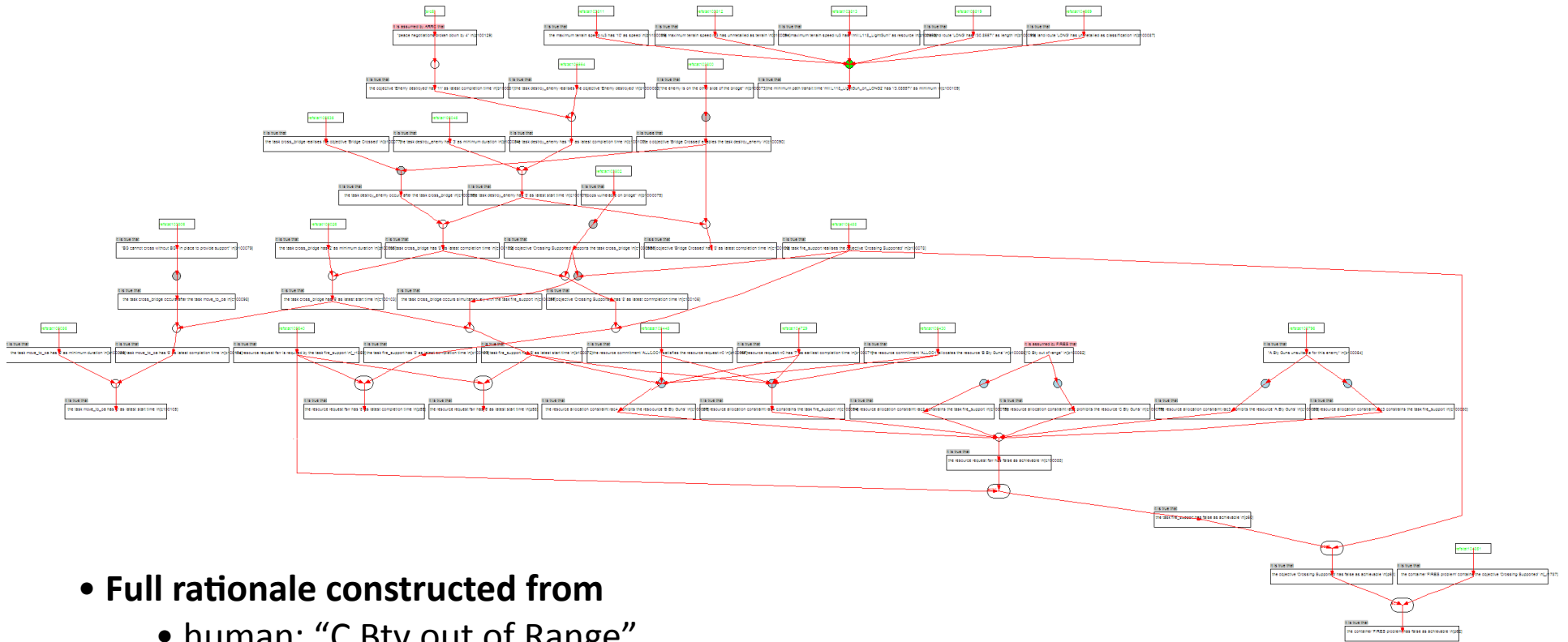
- **Full rationale constructed from**
  - human: "C Bty out of Range"
  - automated: temporal propagation, goal achievement, resource allocation
- **But difficult to grasp in any detail!**
- **"1 page maximum" rule**

it is assumed by ARRC that
"peace negotiations broken down by 4"'

it is true that
the objective 'Enemy destroyed' has '11' as latest completion time

it is true that
the task destroy_enemy has '11' as latest completion time

it is true that
the task destroy_enemy has '8' as latest start time

it is true that
the task cross_bridge has '8' as latest completion time

it is true that
the task cross_bridge has '6' as latest start time

it is true that
the task fire_support has '6' as latest start time

Plan fragment

Enemy destroyed
realises
destroy_enemy
(<8)   (<11)

occurs after

cross_bridge
(<6)   (<8)

has as context
BDE Plan

occurs simultaneously with
supports

fire_support
realises (<6)
Crossing Supported

FIRES problem   is required by

constrains

constrains

fsrr

FIRES Matrix_unallocated

rac4 hibits
B Bty Guns

C Bty out of range   rac2 hibits
C Bty Guns

it is assumed by FIRES that
"C Bty out of range"

it is true that
the resource allocation constraint rac4 constrains the task fire_support

it is true that
the resource allocation constraint rac4 prohibits the resource 'B Bty Guns'

it is true that
the resource allocation constraint rac2 constrains the task fire_support

it is true that
the resource allocation constraint rac2 prohibits the resource 'C Bty Guns'

it is true that
the resource request fsrr has false as achievable

- Relevant assumptions are:
  - **"Peace negotiations broken down by 4":** FIRES cant do anything about that
  - **"C Bty Out of Range":** FIRES needs to justify this assumption [self argument]

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- FIRES asks ready reckoner (RR) service to calculate min travel time for C Bty guns on LONG
- RR uses CE "the l118 light gun moves at 10 km on unmetalled" and terrain map data
- RR returns answer and rationale (as CPM/RDF)

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it is true that
e maximum terrain speed ru3 has '10' as speed

it is true that
the maximum terrain speed ru3 has unmetalled as terrain

it is true that
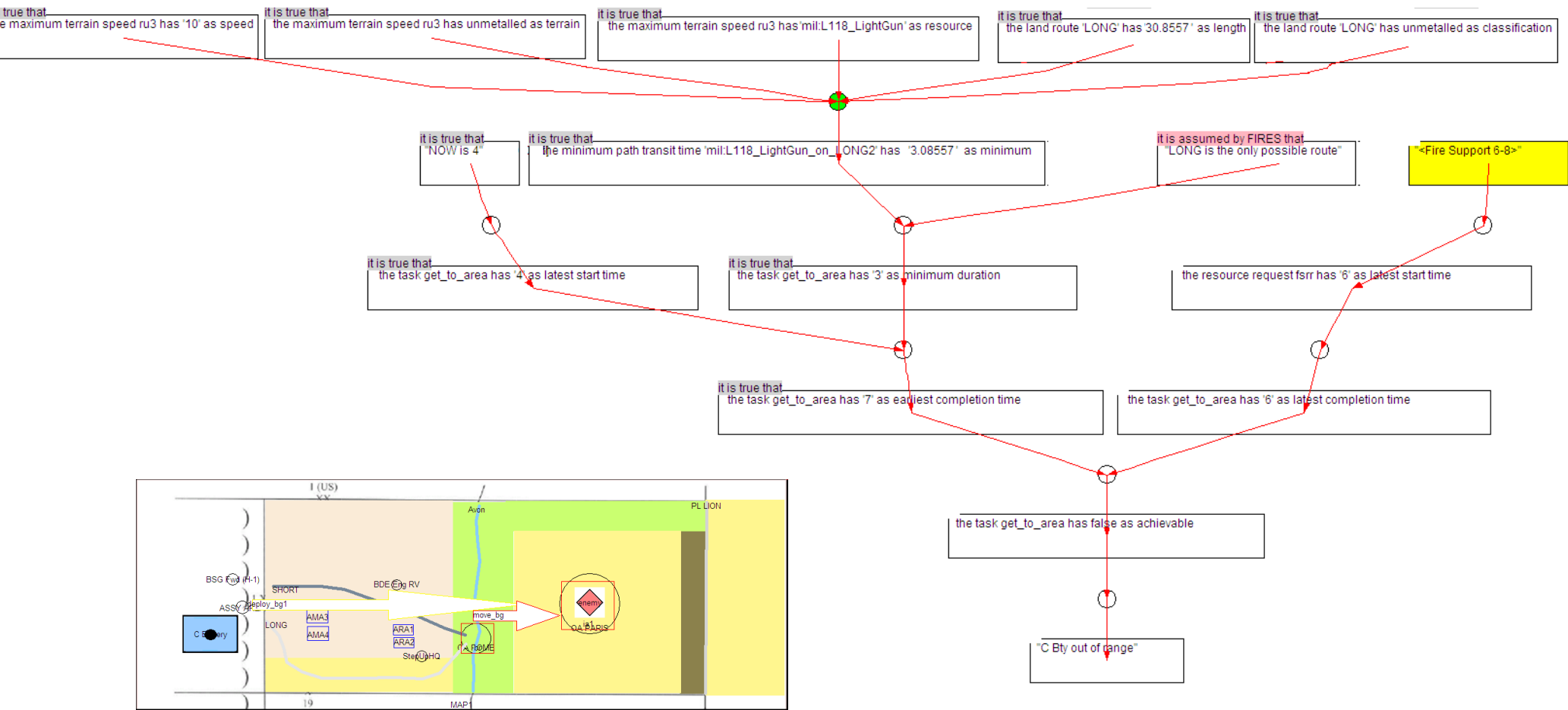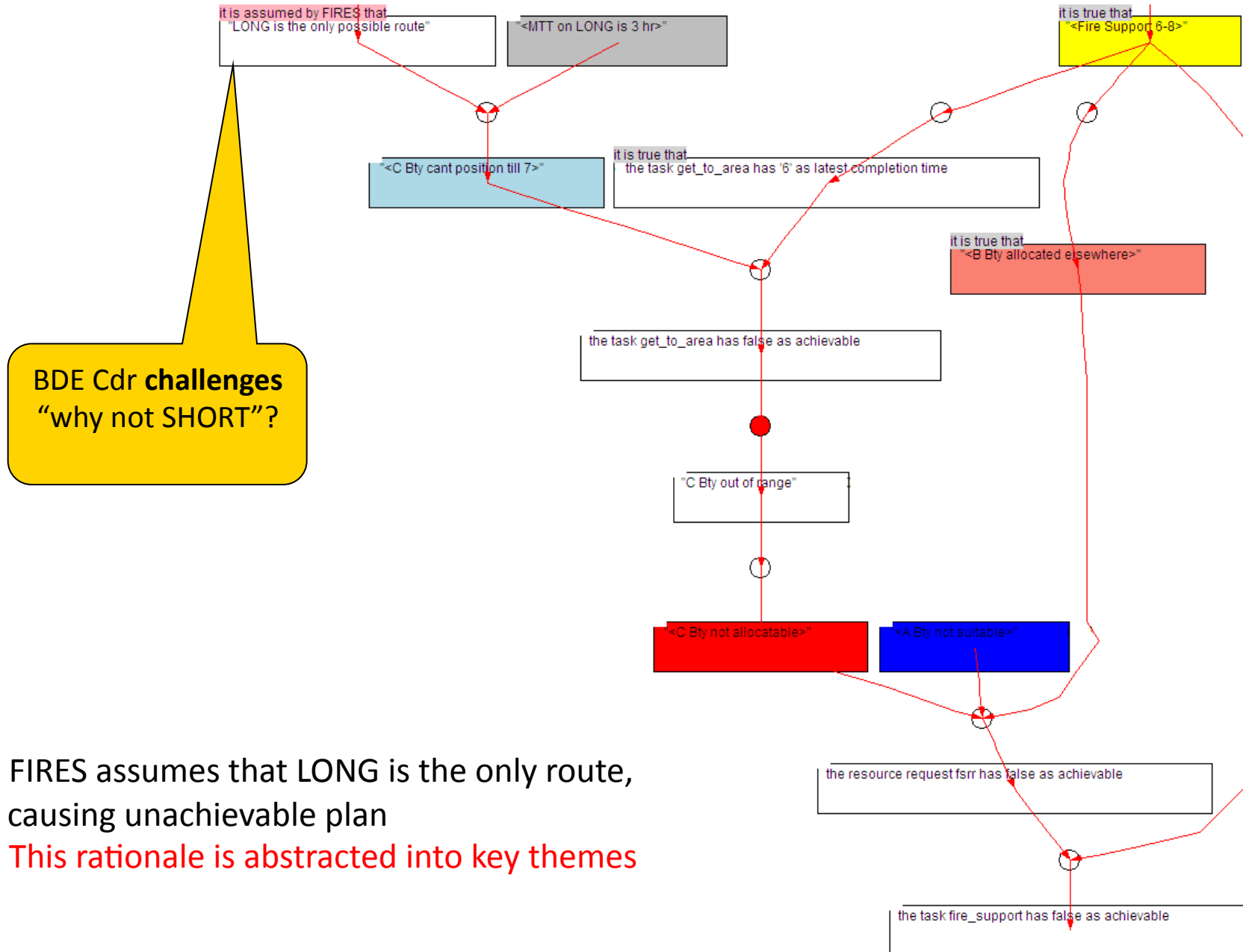the maximum terrain speed ru3 has 'mil:L118_LightGun' as resource

it is true that
the land route 'LONG' has '30.8557' as length

it is true that
the land route 'LONG' has unmetalled as classification

it is true that
"NOW is 4"

it is true that
the minimum path transit time 'mil:L118_LightGun_on_LONG2' has '3.08557' as minimum

it is assumed by FIRES that
"LONG is the only possible route"

"<Fire Support 6-8>"

it is true that
the task get_to_area has '4' as latest start time

it is true that
the task get_to_area has '3' as minimum duration

the resource request fsrr has '6' as latest start time

it is true that
the task get_to_area has '7' as earliest completion time

the task get_to_area has '6' as latest completion time

the task get_to_area has false as achievable

"C Bty out of range"

- FIRES believes that LONG is the only possible route, based on movement of BG1
- Must check his intuition, constructing a "get_to_area" task and see what occurs
- **Formal** - RR service (in green) adds minimum time rationale
- **Informal** - FIRES (in white) creates informal rationale

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it is assumed by FIRES that
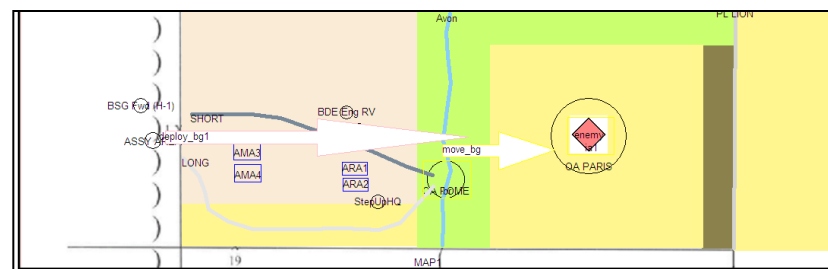"LONG is the only possible route"

"<MTT on LONG is 3 hr>"

it is true that
"<Fire Support 6-8>"

"<C Bty cant position till 7>"

it is true that
the task get_to_area has '6' as latest completion time

it is true that
"<B Bty allocated elsewhere>"

the task get_to_area has false as achievable

"C Bty out of range"

BDE Cdr challenges "why not SHORT"?

"<C Bty not allocatable>"

<A Bty not suitable>"

the resource request fsrr has false as achievable

- FIRES assumes that LONG is the only route, causing unachievable plan
- This rationale is abstracted into key themes

the task fire_support has false as achievable

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it is true that
the task move_to_oa has the resource 'BG1' as executor

it is true that
the task move_to_oa is performed in the intent move deploy_bg1

it is true that
the task move_to_oa has '6' as latest completion time

it is assumed by FIRES that
"Route doctrine states it"

it is true that
"BG1 using SHORT"

it is true that
"cannot share SHORT with BG1"

it is true that
"SHORT not available"

it is true that
"LONG is the only possible route"

Plan fragment

"Route doctrine states it"

move_to_oa

(<6)

BDE Plan

• BG1 is using route SHORT up until 6
• Route Doctrine: cant share Guns with Brigade

BDE Cdr indicates this can be overruled, making SHORT available

it is assumed by BDE Cdr that
"Tactical Override"

tat105091

refstat105629

[src134] ratvis states that

it is true that
the task move_to_oa is performed in the intent move deploy_bg1

it is true that
the task move_to_oa has '6' as latest completion time

it is inconsistent that
"Route doctrine states it"

resource 'BG1' as executor

it is true that
"BG1 using SHORT"

it is inconsistent that
"cannot share SHORT with BG1"

it is inconsistent that
"SHORT not available"

Assumption by FIRES

it is inconsistent that
"LONG is the only possible route"

- FIRES' assumption about Route Doctrine that leads to plan failure is exposed
- Countered by the BDR Cdr as an override due to "tactical imperative"

Crossing Supported
uses
fire_support

FIRES problem

collaborates with

Advance to OA Rome

is required by

FIRES Plan

constrains

constrains

fsrr

is required by
FIRES Matrix_unallocated

constrains

rac2
prohibits

A Bty Guns

rac3
prohibits ALLOC1
allocates
satisfies

B Bty Guns

rac1
prohibits

C Bty Guns

FIRES Matrix_allocated
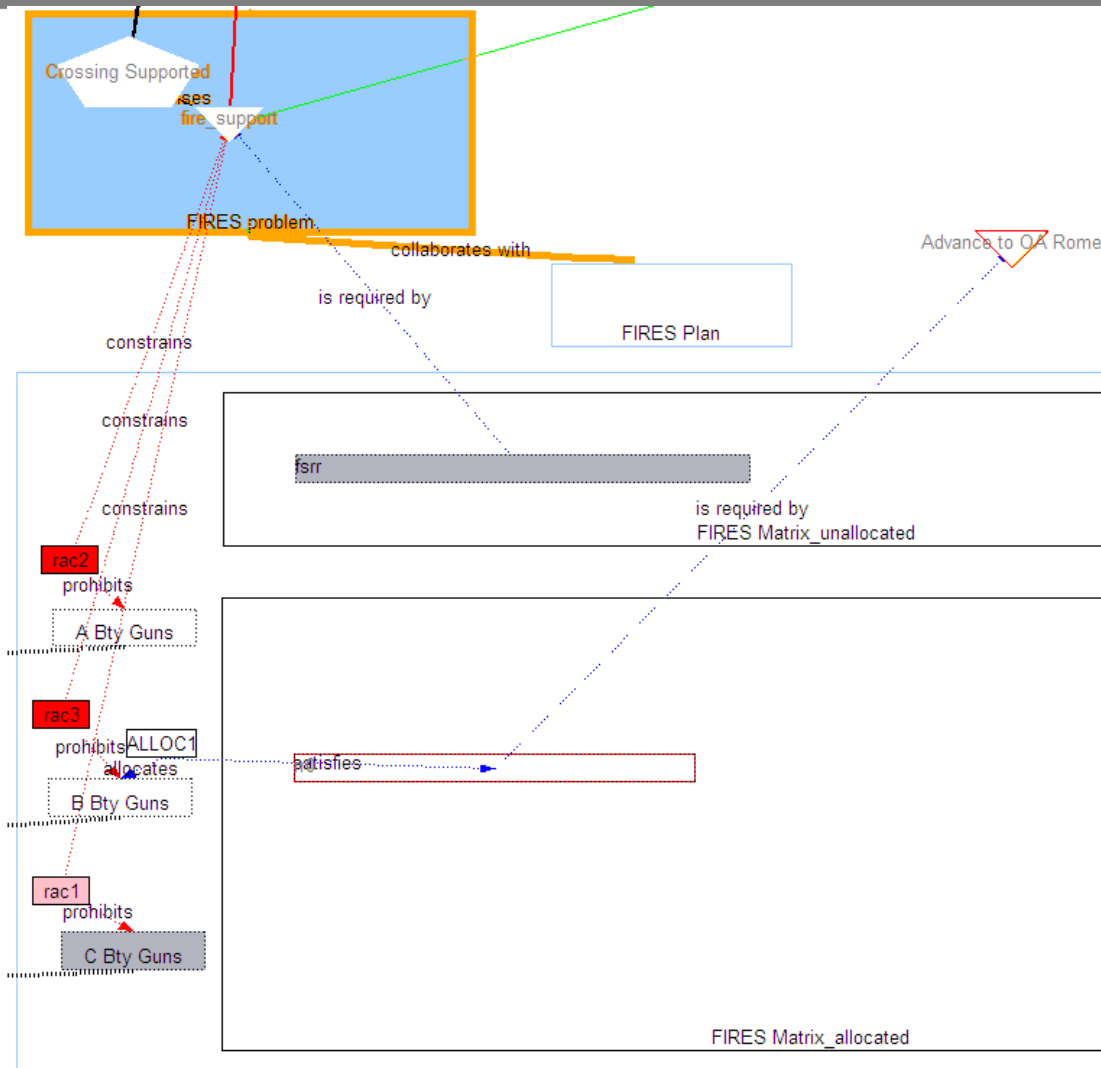
- System can calculate the consequences of removing the doctrine assumption
- C Bty guns now available for allocation to fire support request

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SUMMARY OF EXAMPLE

- Based on "Dragons Sword" scenario, from the UK Land Warfare School

- Misunderstanding between two planners, leading to failure to achieve a plan

- Exploration of rationale used to uncover hidden assumption

- Removing assumption enables plan completion

- "This problem is endemic in military planning" (LWS)

- Rationale, argumentation, challenge/response could help in achieving shared understanding

Some principles for automation

ITA Controlled English

ITA CONTROLLED ENGLISH

- A Controlled Natural Language is a human readable subset of English that can also be machine parsed
  - Improves "impedance matching" between human and agent as both can use the same language
  - A number of CNLs have been developed

- We use ITA Controlled English (CE)
  - "Inspired by" draft of Common Logic Controlled English (John Sowa)
  - We have extended it to cover assumptions, argumentation, …
  - User can state facts, assumptions, rules, new conceptual models in CE
  - User can extend syntax
  - Rationale graphs in CE

- Our experience suggests that it is powerful to use:
  - Non logical user can express facts, queries, and rules
  - Using CE as primary representation throughout the system leads to common semantics across sub-systems and also (surprisingly) flexibility and creativity in design

Synchronisation between Visualiser and Rationale

- Synchronised display of plan and rationale
  - select plan entity and see rationale
  - select path in rationale and see plan entities
- Ontology logic binds visualiser and rationale
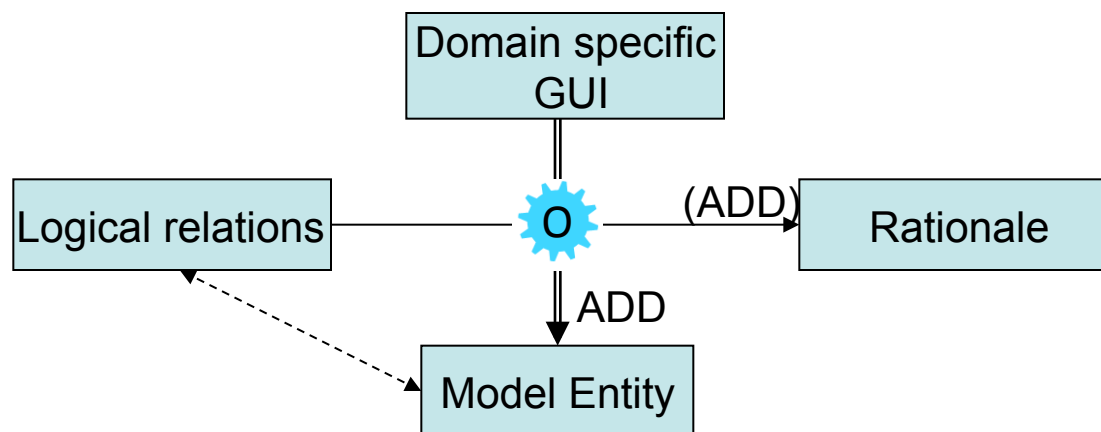
Nature of entities	GUI	Rationale
Resource allocation constraint		the agent 'FIRES' states that the resource allocation constraint rac2 constrains the task fire_support and prohibits the resource 'A Bty Guns' because "A Bty Guns unsuitable for this enemy".
"intention" links between tasks and objectives		the task destroy_enemy occurs after the task cross_bridge because the task cross_bridge realises the objective 'Bridge Crossed' and the objective 'Bridge Crossed' enables the task destroy_enemy.

- Linkages could be automated by logic from the ontology (partially implemented)

Hybrid Rationale

Hybrid rationale

- Reasoning should be a collaboration between automation and human

- Human reasoning may be structured or unstructured

- Total rationale should be integrated in a single view

- But may lead to large graphs which are more difficult to follow
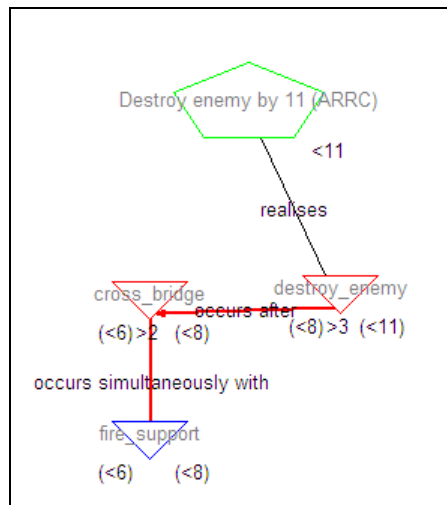
Domain Application
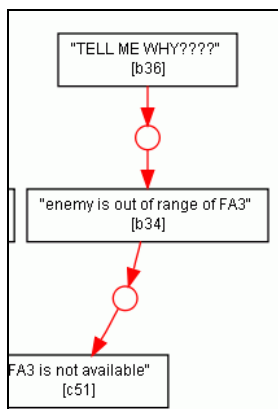
Argumentation "Patterns"
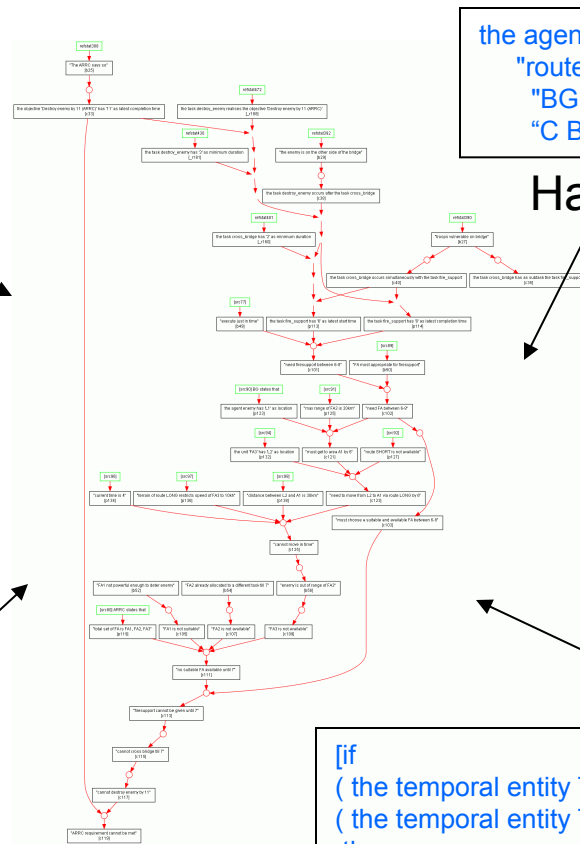
the agent FIRES states that
"route SHORT is not available between 4-6" because
"BG1 using SHORT between 0-12" and
"C Bty and BG1 cannot use SHORT simultaneously".

Handwritten User Rationale

[if
(the temporal entity T has the value X as earliest completion time) and
(the temporal entity T1 occurs after the temporal entity T)
then
(the temporal entity T1 has the value X as earliest start time)
.

Automated Reasoning

STRUCTURED AND UNSTRUCTURED RATIONALE

- **Rationale defined in Controlled English**

  - SENTENCE1 because SENTENCE2

  - May contain structured facts and/or unstructured text

- <u>**Structured facts**</u> **can match logical rules allowing further inferences**

    the task destroy_enemy occurs after the task cross_bridge
      because
    the task cross_bridge realises the objective 'Bridge Crossed' and
    the objective 'Bridge Crossed' enables the task destroy_enemy.

- <u>**Unstructured text**</u> **can represent information impossible to capture in the model but the internal detail cannot be used to match rules and generate new inferences**

    "SHORT not available"
      because "BG1 using SHORT" and "cannot share SHORT with BG1"

- **But possible to have a rationale graph based on unstructured text, or a combination of structured and unstructured**

- <u>Unstructured</u> – good for informal human reasoning
  - Easy to write
  - Likely to be smaller
  - But may miss key reasons
- <u>Structured</u> – good for ensuring all dependencies are captured and the links are logical
  - But large and may be too finely granulated
- Must be able to move between them
  - Start with rough and add more detail
  - Take a detailed graph and abstract to simpler one
- This exploration may help the user to validate and define new aspects of the ontology

Abstraction — grasping large graphs
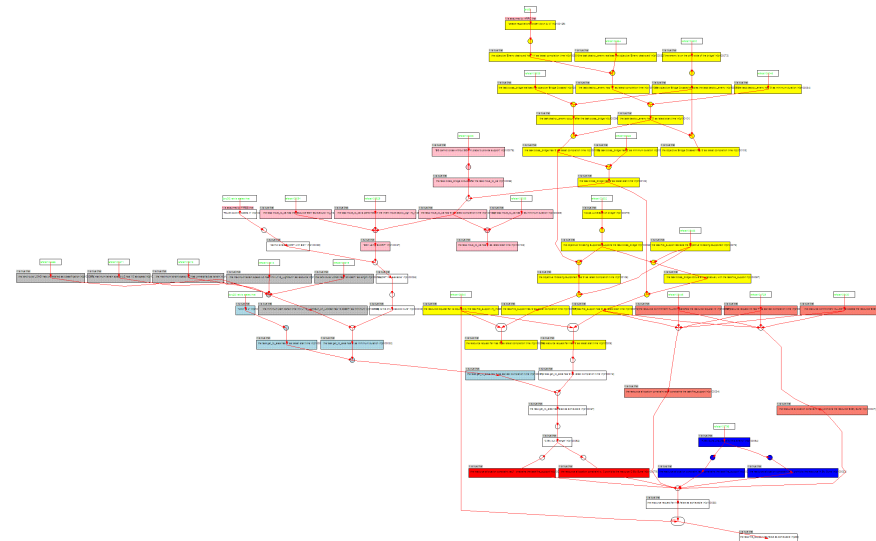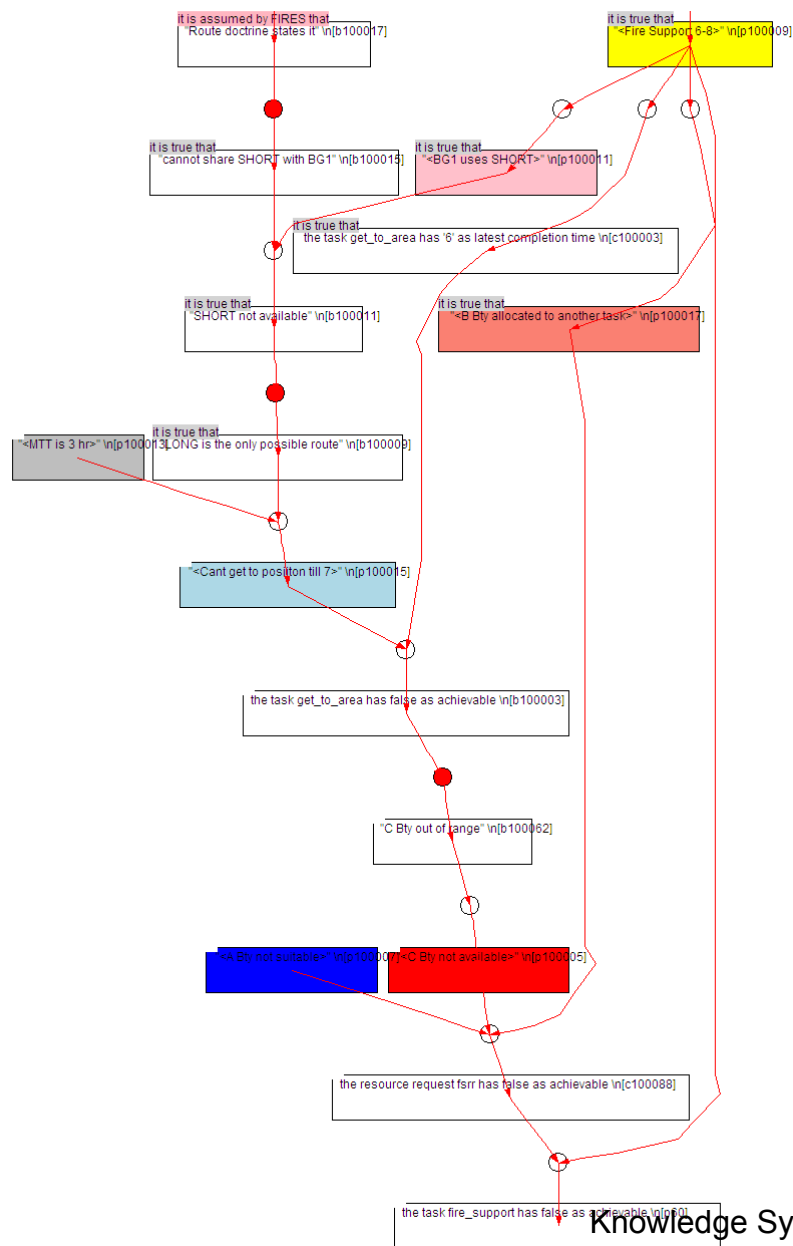
- User groups nodes and abstracts to an unstructured proposition, eg "fire support 6-8"
- Grouping depends on what you want to present
- Allows movement between structured and unstructured
- CE could be used to express the abstraction. Could this be used to create new rules or concepts?

- Systems need to communicate rationale

  - ready reckoner

  - Sub planning systems

- ITA "Logic proposal" offers a way to represent rationale in OWL/RDF

  - Implemented in IBM/Boeing exchange of plans and in ACITA demonstration

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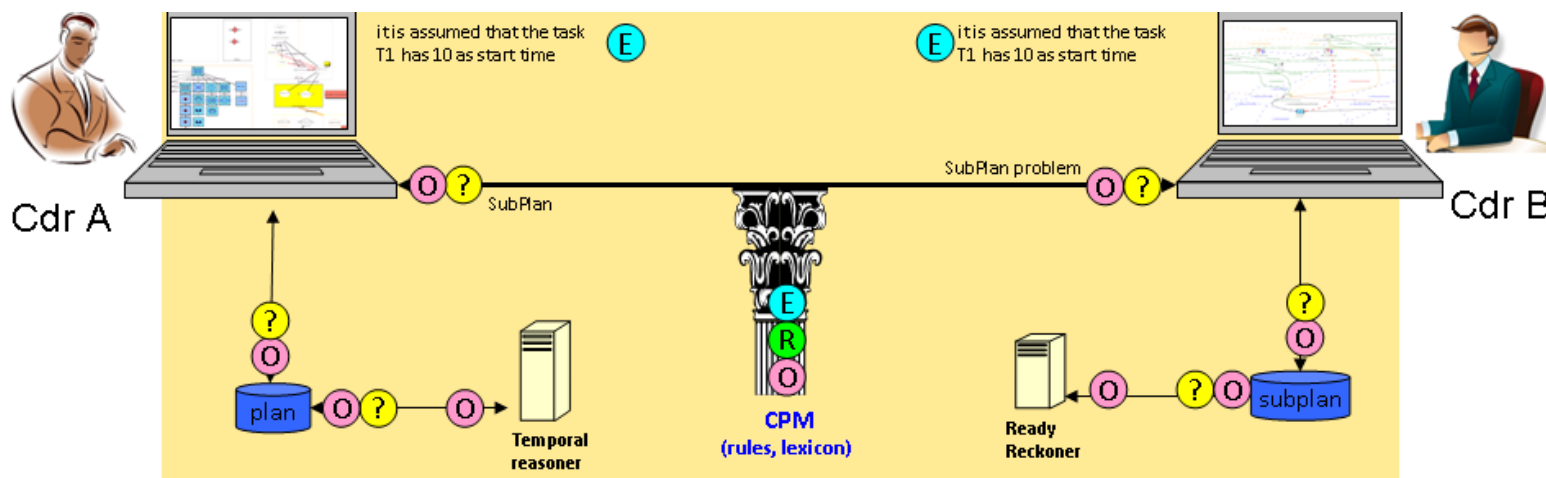
Patterns of Rationale

ARGUMENTATION AS A RATIONALE PATTERN

- Patterns of challenge and response
  - Why did you say that?
  - Your fact is wrong
  - Your reasoning is wrong
  - Can expose hidden assumptions and incorrect reasoning

- Visualiser can assist the exploration of the rationale graph by addition of standard "patterns"
  - Claim, Justify, Rebut, Undercut
  - Using CE to represent the argument:

    in the argumentation arg1,
        by stating that "Tactical imperative allows me to override"
        the agent 'BDE Cdr' disputes the claim that "Route doctrine states it" .

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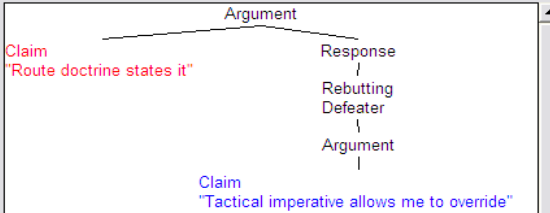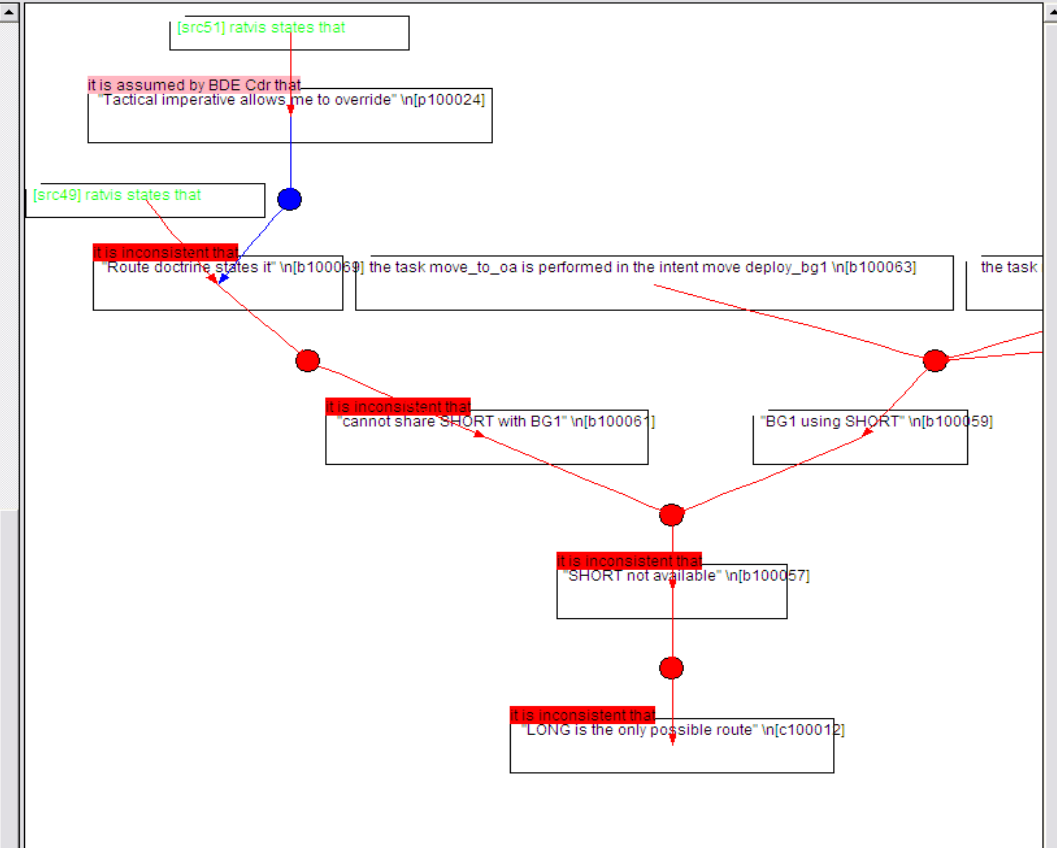
Working with CUNY to explore this idea

- User clicks on rationale graph to add "Rebut Claim"
- Argumentation CE generated in orange, and the corresponding rationale in blue
    - Attempting to construct semantics of argumentation via:

Argumentation CE $\longleftrightarrow$ Rationale CE

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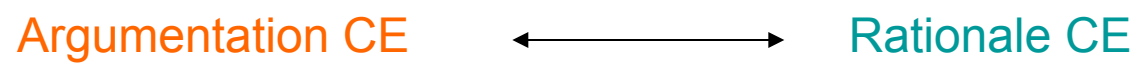
Military Application

MILITARY APPLICATION - ANALYSIS

- **UK:** the example is validated as a realistic situation where rationale exploration is of benefit

- **US:** the US Military Decision Making Process (MDMP) for coordination and synchronisation of plans has stages where rationale is important:

  - In Mission Analysis the Commander and staff expand the details of, and verify, the Mission

    - they may challenge FIRES rationale, develop shared understanding of route doctrine constraints and how this influences resource availability

  - In COA Analysis, the staff compares distinct Courses of Action and recommends one to the Commander

    - during the synchronisation of the Battlefield Operating Systems, the planning staff may challenge the rationale for not using C Bty Guns, leading to shared understanding of the route doctrine constraints, allowing the Commander to respond with a waiver

MDMP

MDMP
Mission receipt
Mission analysis
COA development
COA analysis
COA comparison
COA approval
Order production

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- Once the MDMP is complete, the staff rehearse the chosen COA, ensuring that the staff understand the commander's intent and to visualise the concept of operations, e.g. Rehearsal of Concept (ROC drills)

- This provides an opportunity to identify erroneous assumptions via the challenge/response to rationale
  - Planners talk through the rationale for tasks one to two levels up
  - Rationale is communicated in the command intent for effects
    - DESTROY enemy in order to "Clear route of enemy forces"
  - Unresolved problems are presented to the Commander for resolution

- However rehearsal does not always tease out hidden assumptions
  - After Action Review (AAR) led by Commander may finally expose assumptions

Level-2

↑ in order to

Level-1

↑ in order to

My tasks
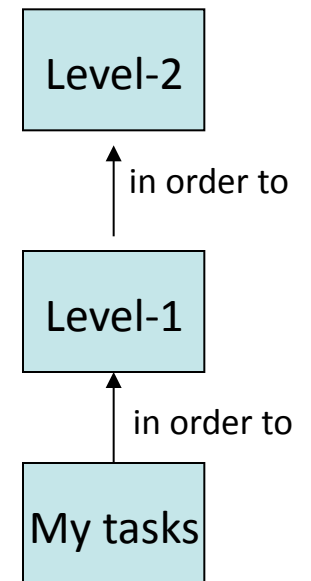
EVALUATION

- Planning an evaluation of the CPM in a multiuser military scenario
  - Exchanging plans

- Aiming to add some capture and passing of rationale

- Utility of rationale?
  - Amount of requests for further "why" information
  - Degree of frustration exhibited by collaborators:
    - Why do I have to do this?
    - What is (s)he trying to do here?
  - Degree to which rationale is "made up" to fill the gap

- Informal experiment by observation
  - Probably won't have a control group

Shared Understanding?

- **We believe that shared understanding is supported by**:

  - exchange of rationale in CE between different systems

  - synchronisation of the rationale to the basic problem solving entities

  - facilitating "abstraction" of the key themes in the rationale

  - use of challenge/response argumentation patterns to expose assumptions

- **We believe that this is relevant and important in the military context**

- **We need to evaluate it, as part of the CPM evaluation**

THANK YOU