



# Towards Systematic Model-Based Development of Patient Management Systems

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# Outline



- Brief project overview
  - Long Term Goal
  - Sepsis and the ICU
- Early Warning: The Listening Application
  - Preliminary Data
- Improving Compliance: Process Management
  - A Prototype and Plan for Improvement
- Clinical Trial and Implementation



- Provide electronic support for complex decision making in health care which improves quality of care. Make tools that analyze patients' electronic records and...
  - Assist in diagnosis of multiple diseases.
  - Improve adherence to evidence-based guidelines in disease management.



# Sepsis and the ICU...



- Sepsis

- Common, Deadly
- Affects inpatients
- Difficult to diagnose
- Early treatment is superior
- Effective treatment requires an array of multi-step interventions.

- The ICU

- Instability in multiple organ systems
- Information rich
- Decision rich
- Rapidly growing use of protocols



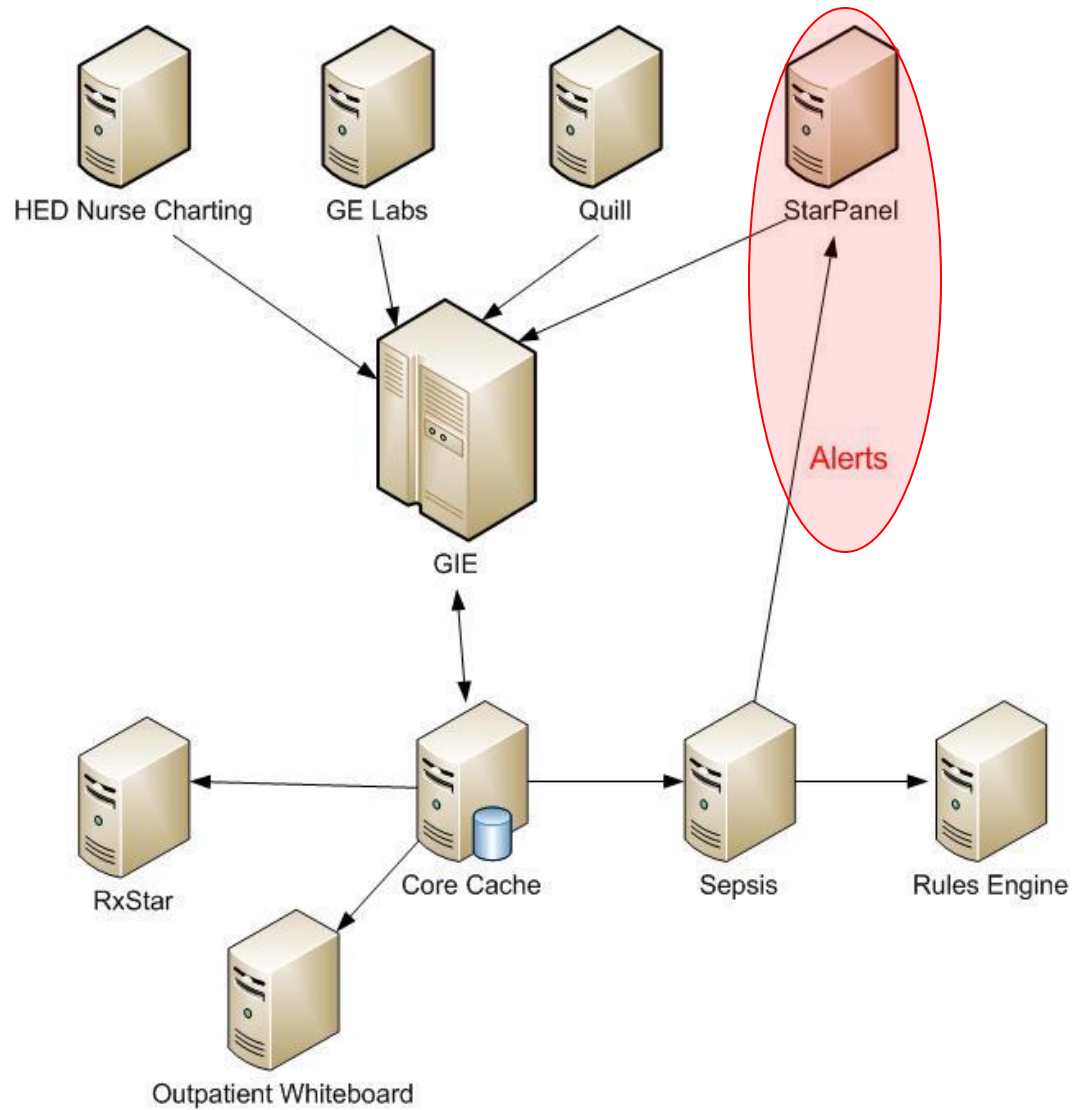
- An application positioned within our system to monitor patient data (flow sheet data, laboratory data, etc.).
- Programmed to generate alerts to physicians (via the dashboard and pager system) when certain criteria are met.
- Rules engine able to “filter” alerts and ensure that only new or pertinent alerts are generated.
- May be applied to many disease processes.



- Applied to sepsis in our pilot project.
- Monitors for modified SIRS criteria.
- When criteria are met,
- Rules engine ensures that information is new and pertinent.
- Has been deployed in the MICU and SICU.



# Listening Application





# The Listening Application



Preliminary Data from the MICU (80 pts.):

- 100% sensitive for sepsis
- ~60% specific for sepsis
- Did not alter behaviors, including time to 1st antibiotics, time to change of antibiotics, ICU time, vent time, shock time, mortality.
  - This is not unexpected within the MICU, where provider:patient ratio is low, suspicion for sepsis is high.
  - 10% of patients had not received antibiotics at the time of the alert...

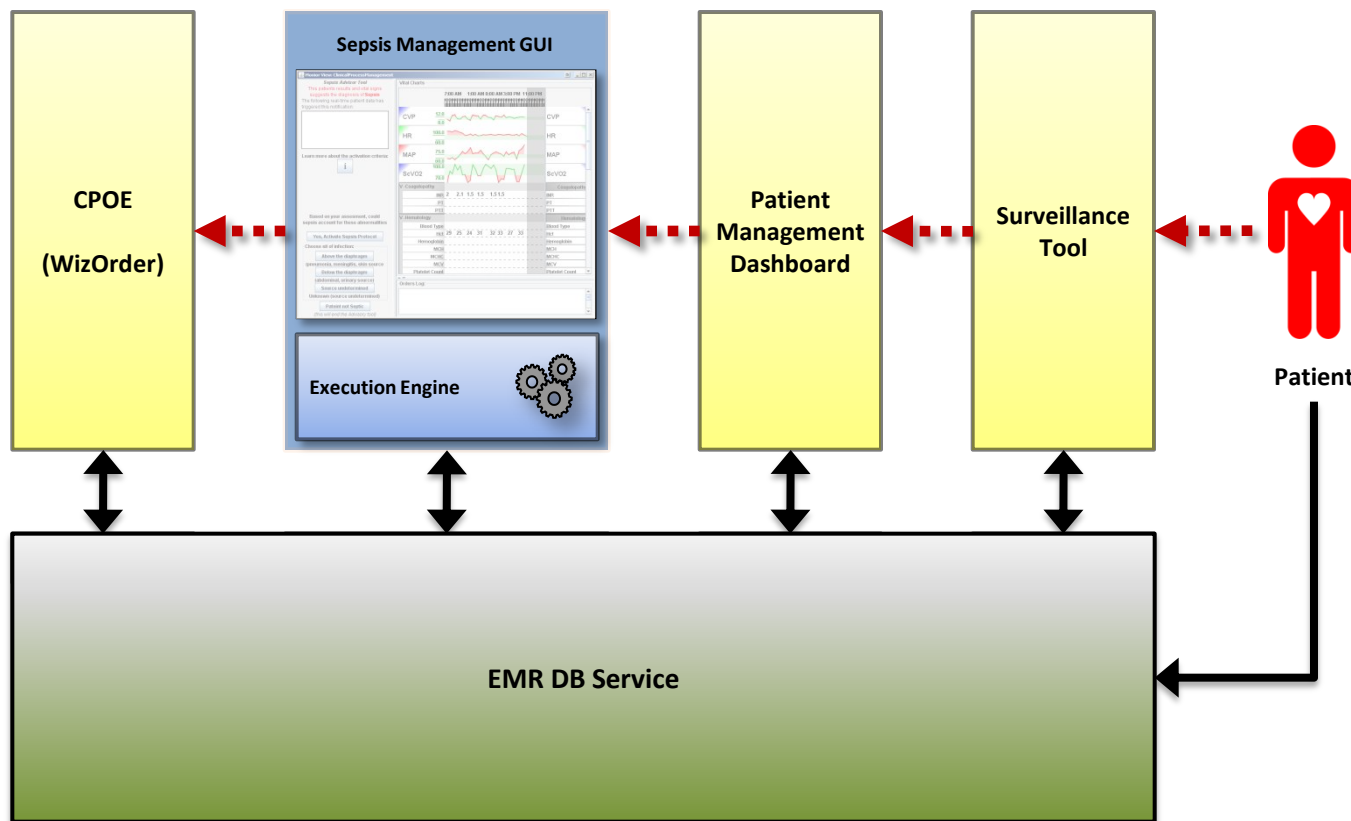




# Sepsis Management System



Physician



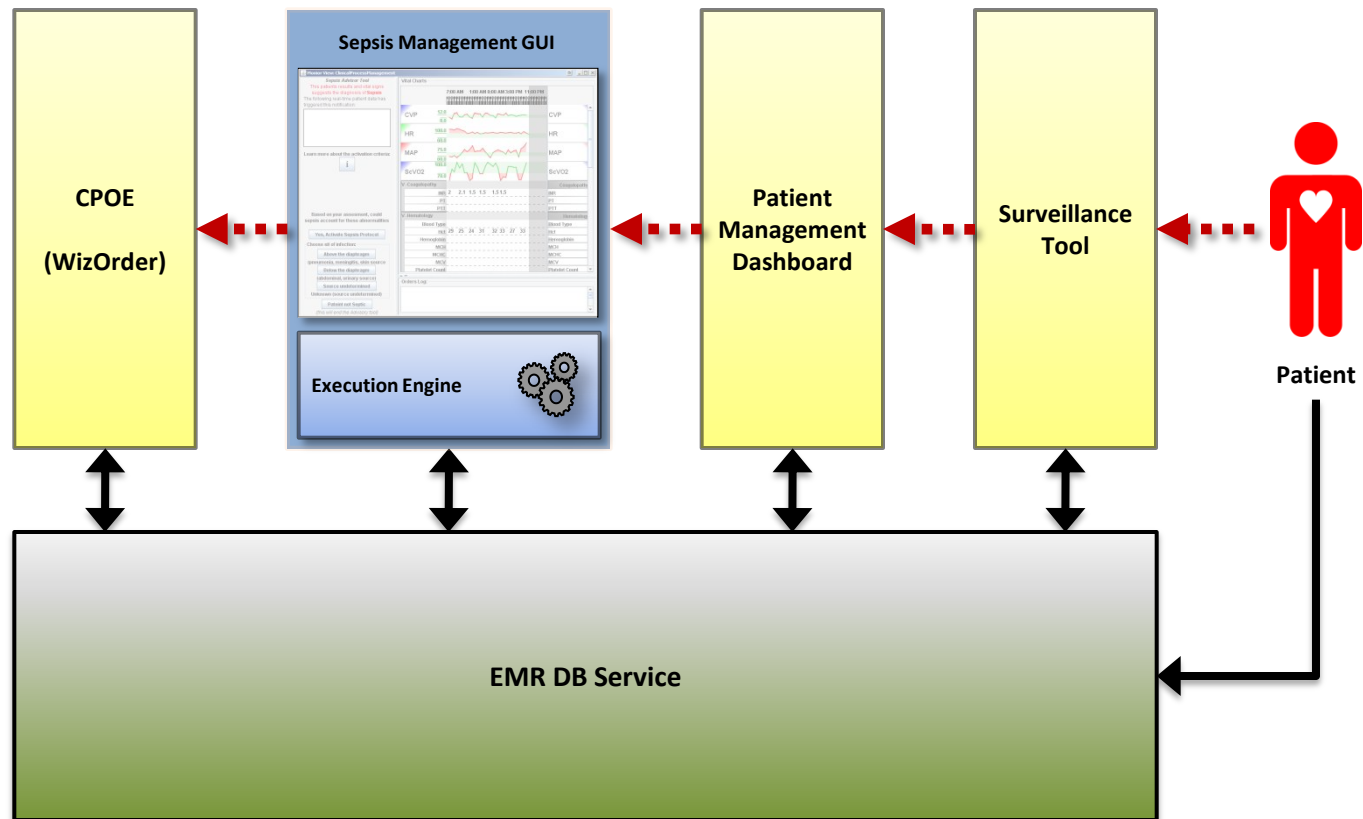
1. Identify patients based on modified SIRS criteria
2. Prompt clinical teams
3. Provide real-time process management recommendations based on live patient data
4. Process confirmed orders



# Creation and Deployment of Treatment Models

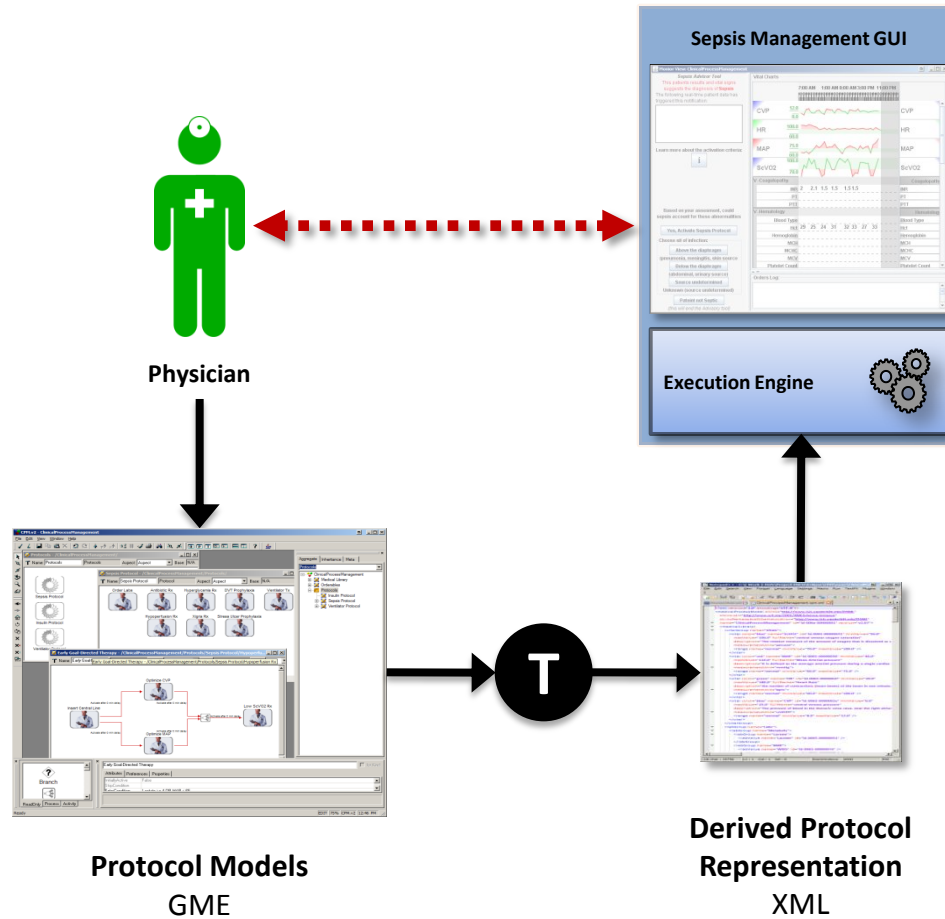


Physician



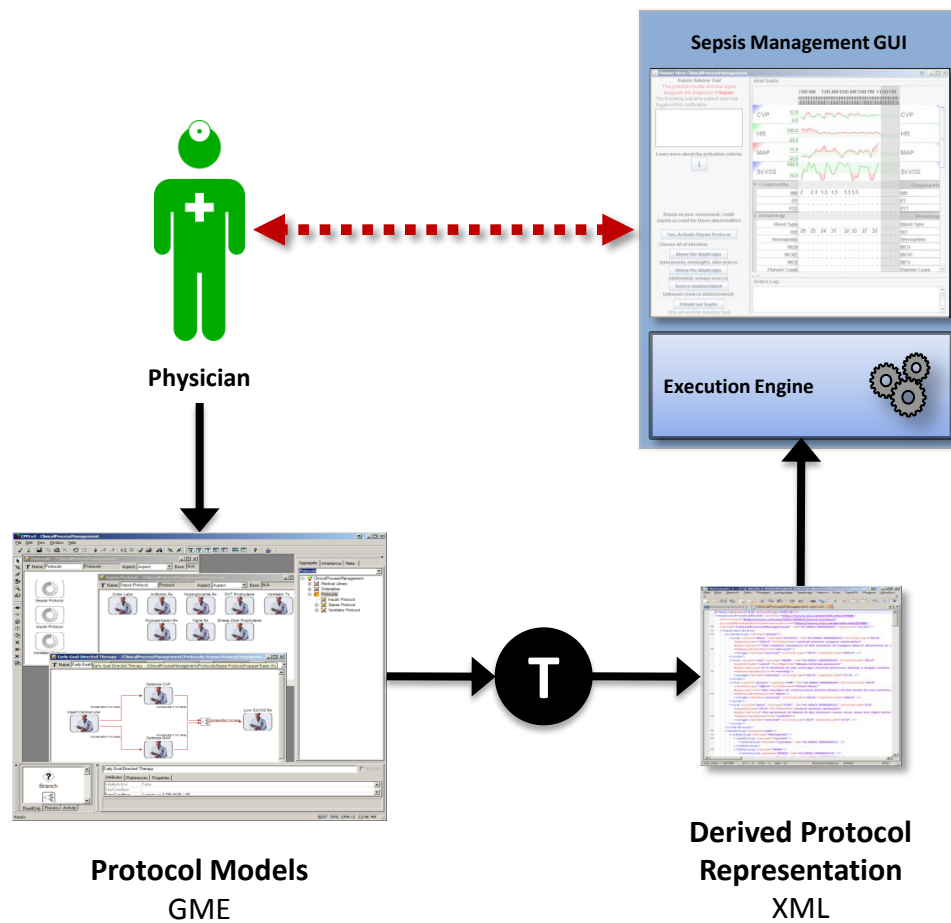


# Creation and Deployment of Treatment Models



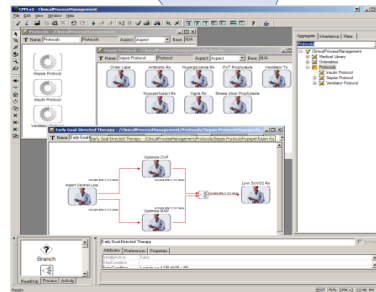
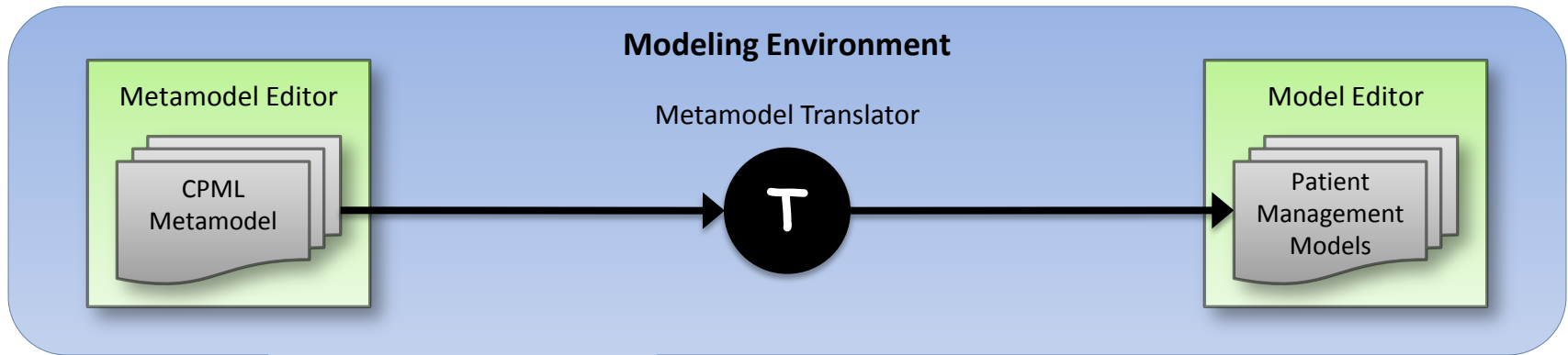


# Design of the Clinical Process Modeling Language

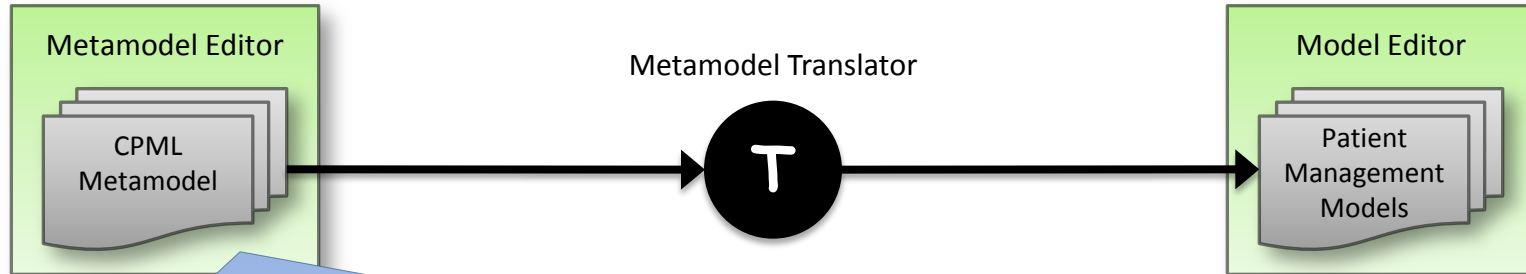




# Inside the Modeling Environment 1/9



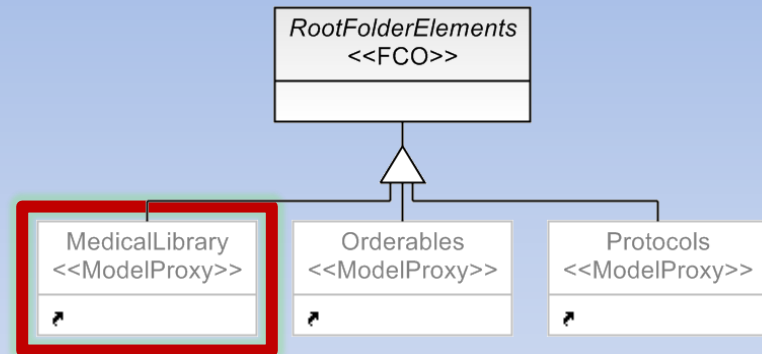
**Protocol Models**  
GME



## Medical Knowledge

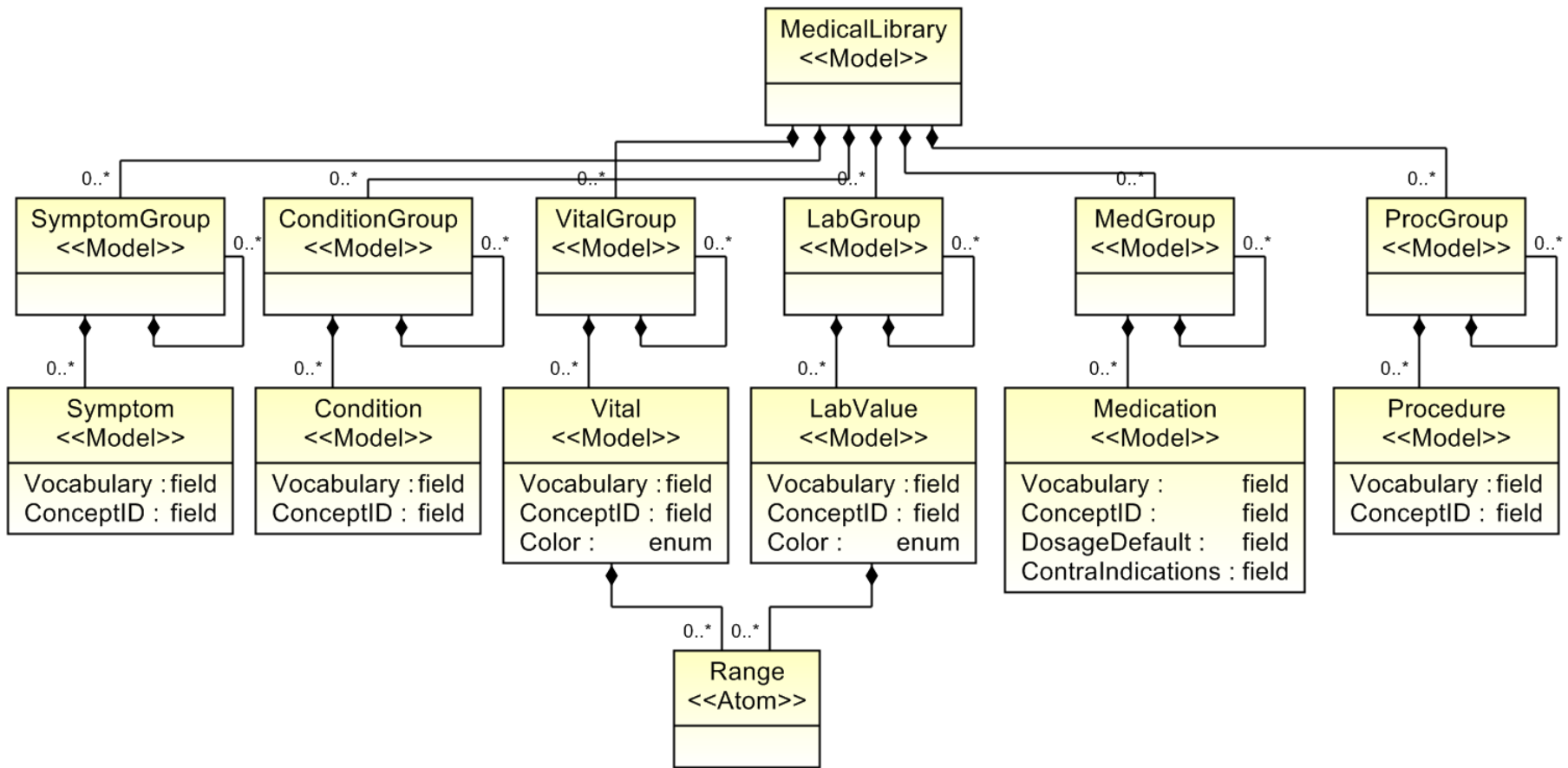
1. General medical ontology

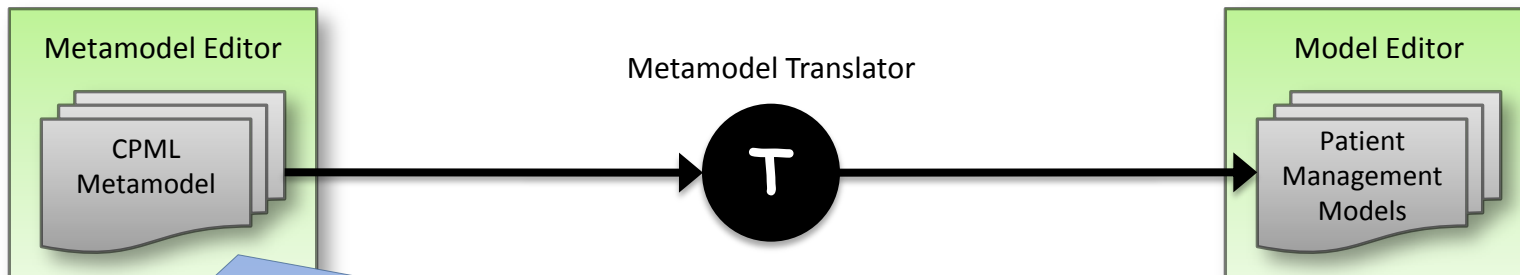
## CPML





# CPML: Ontology Elements

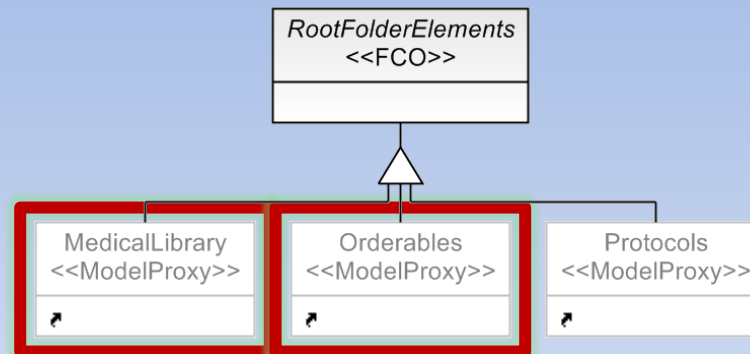




## Medical Knowledge

1. General medical ontology
2. HCO-specific ontology

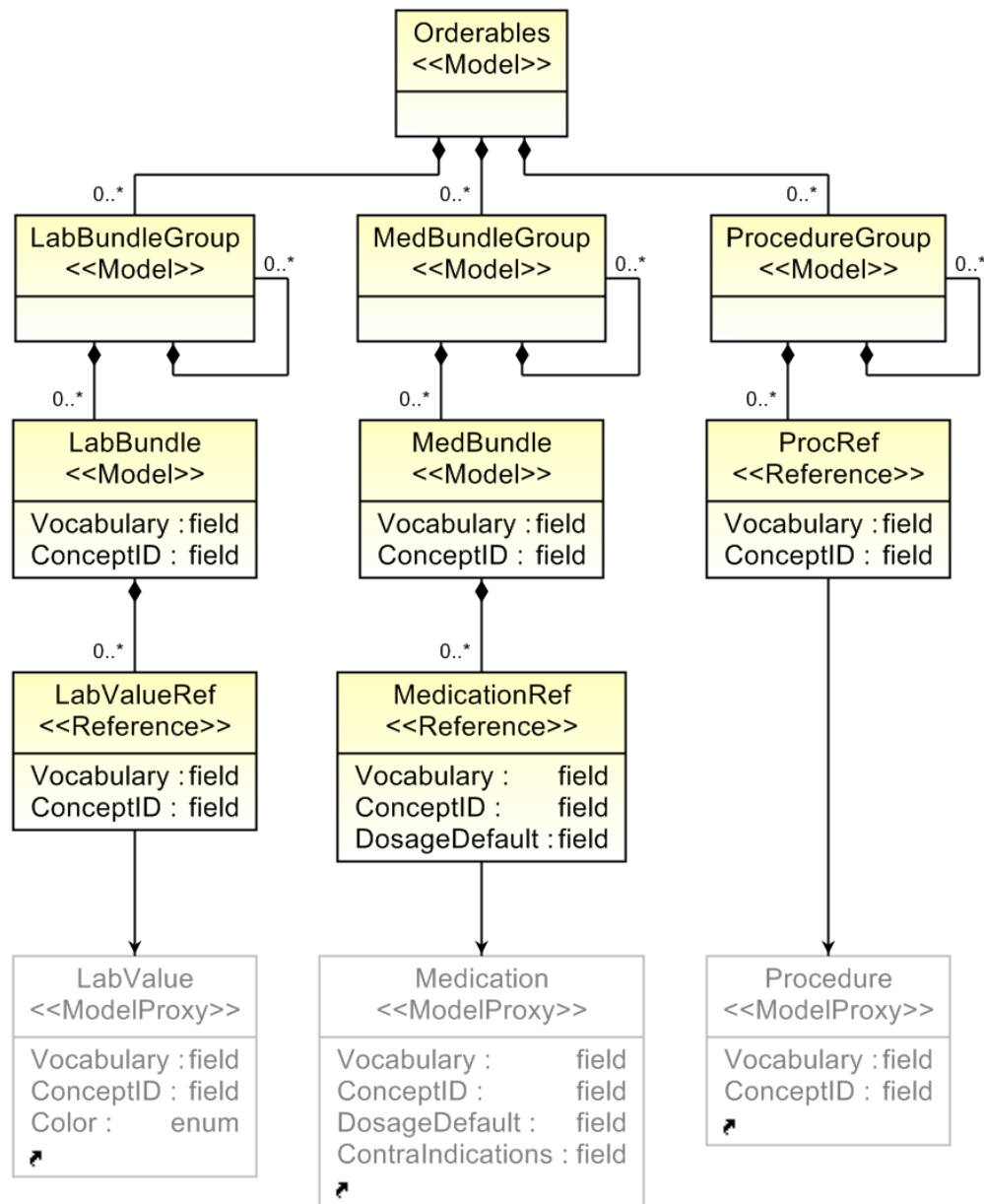
## CPML

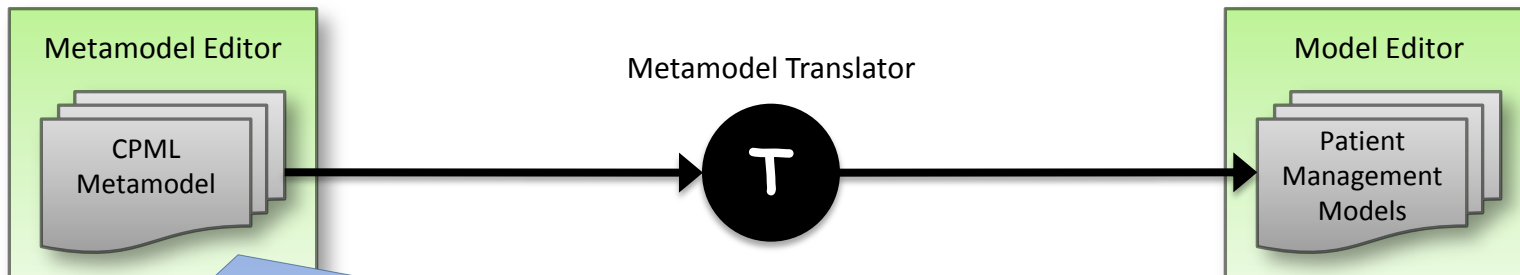






# CPML: HCO-specific Ontology

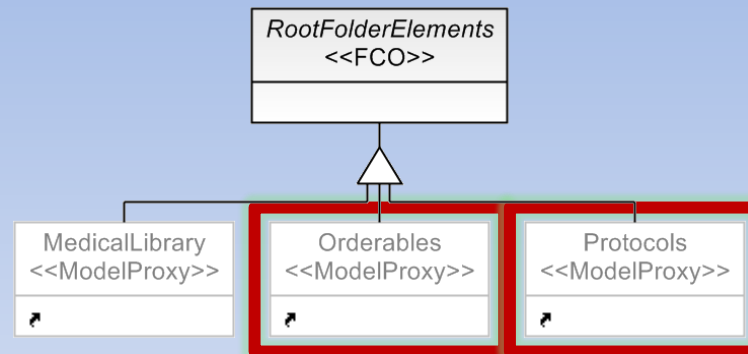




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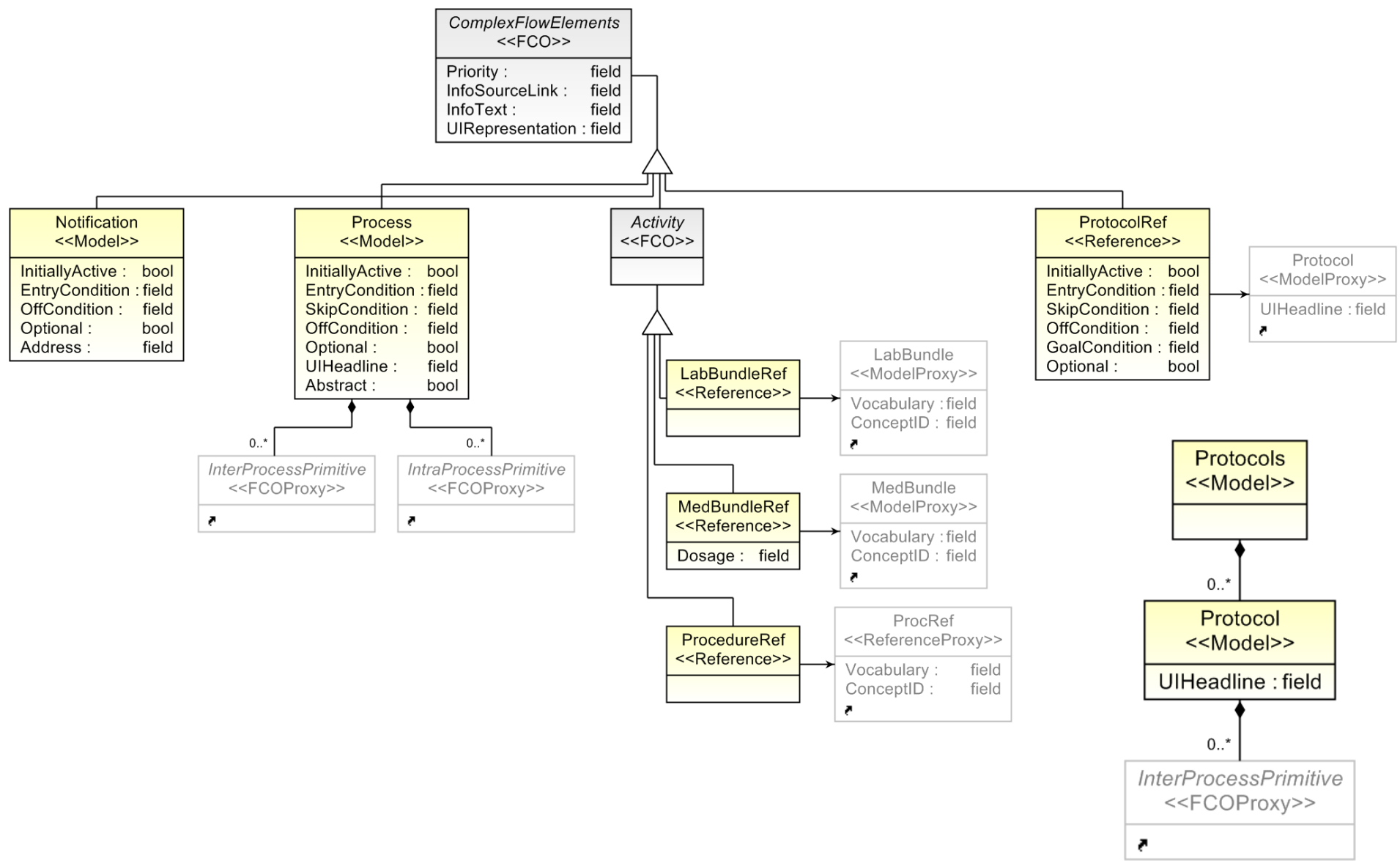
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2. HCO-specific ontology
3. Patient management protocols
  - Conditions
  - Constraints and Well-formedness Rules
  - Execution Flow
  - Composition

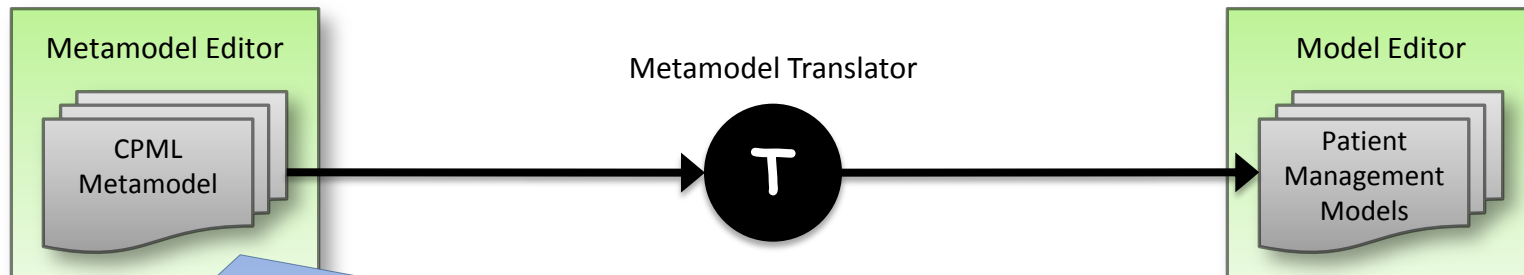
## CPML





# CPML: Patient management protocol

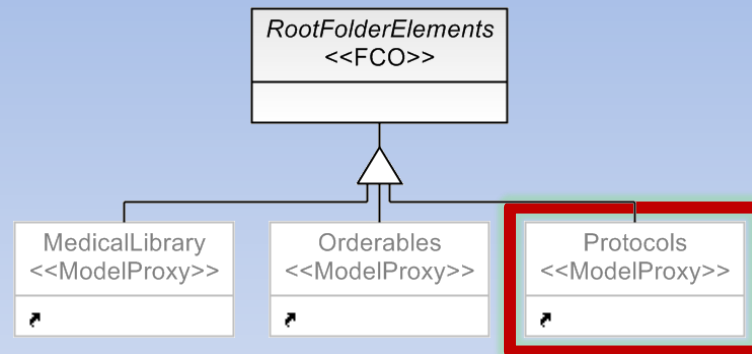




## Medical Knowledge

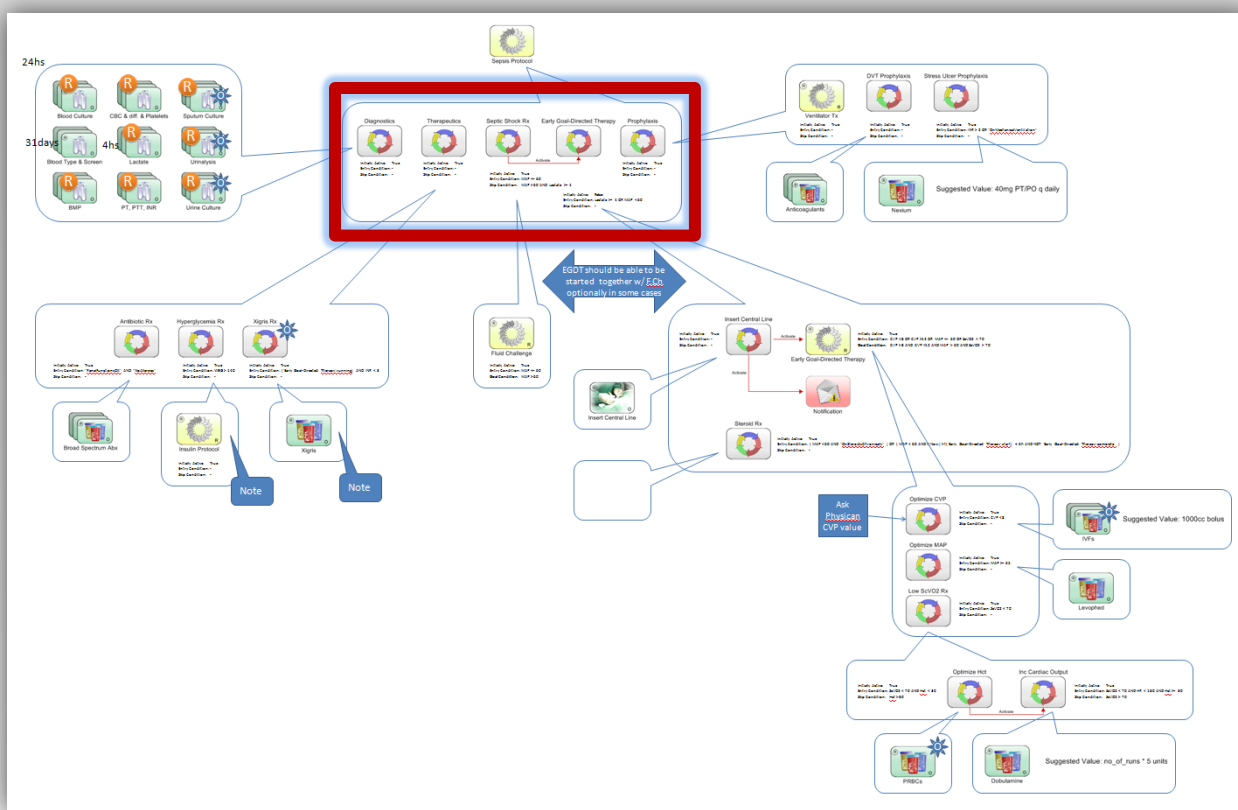
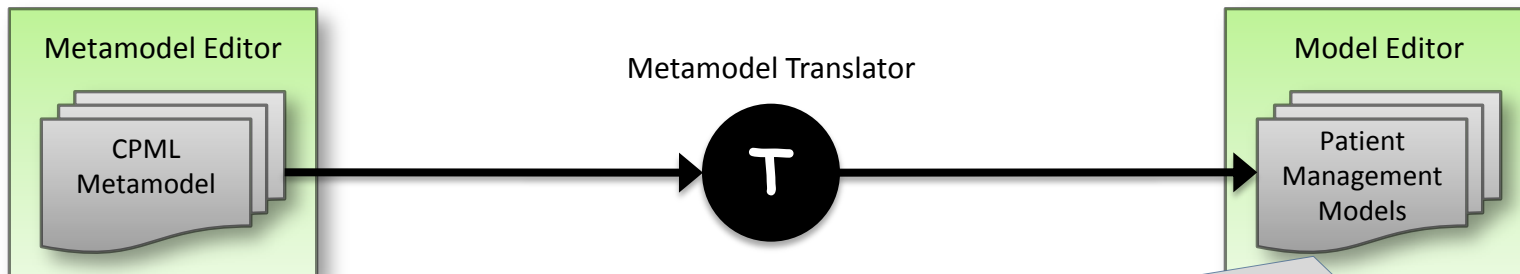
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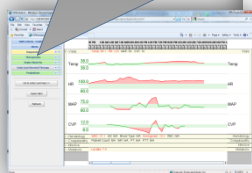
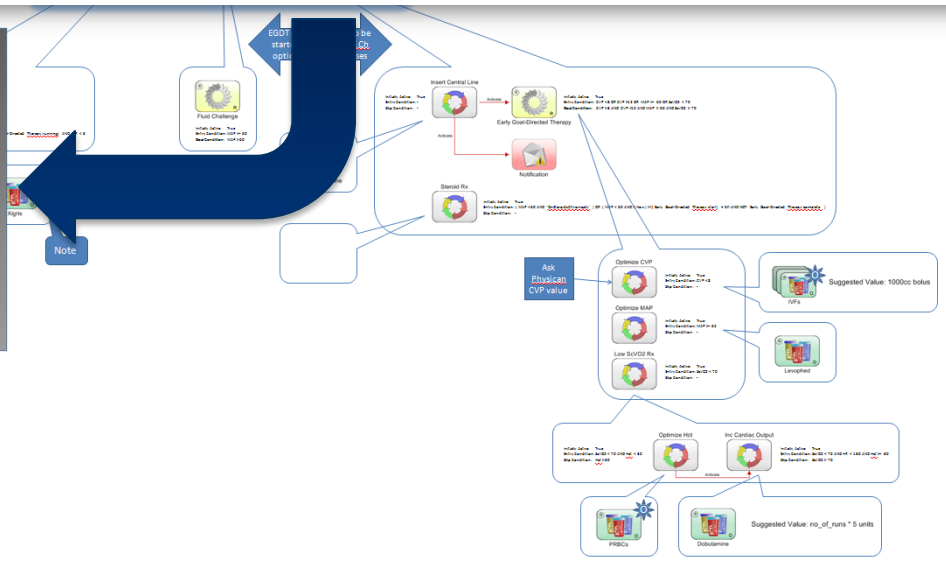
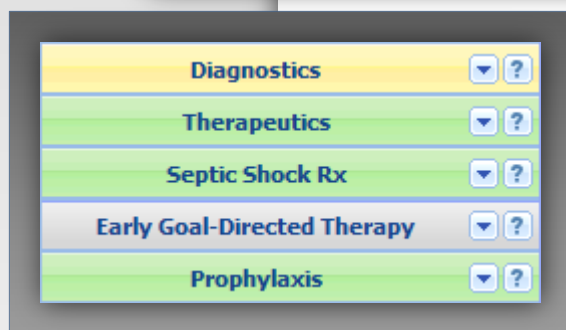
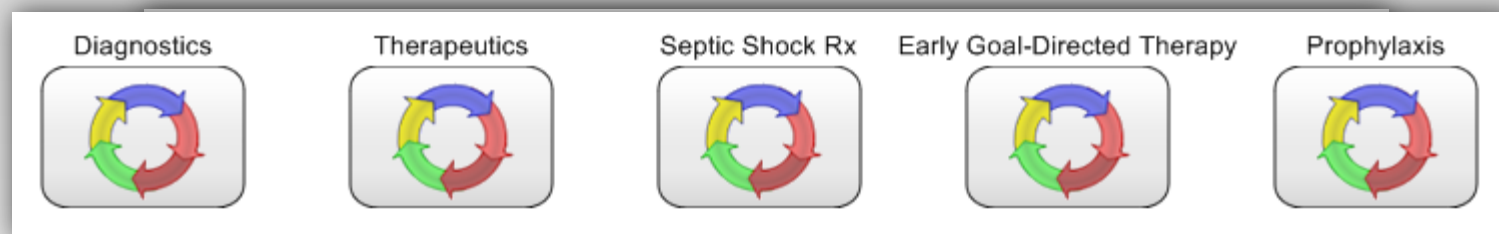
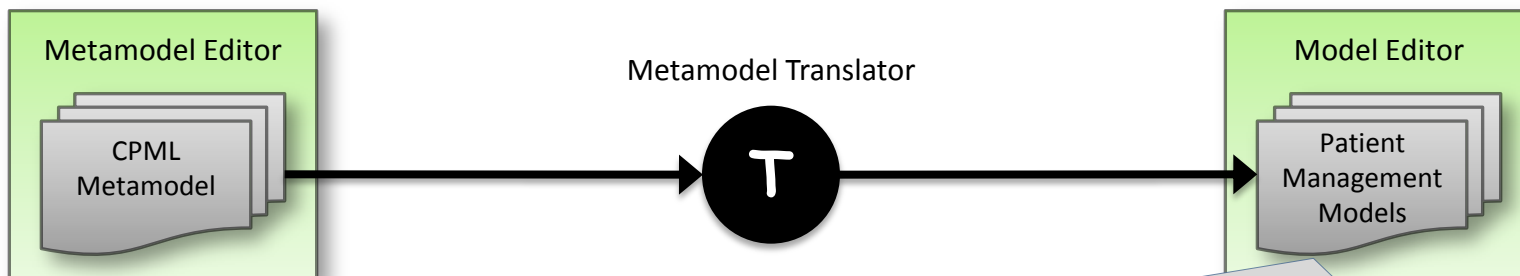


# Inside the Modeling Environment 7/9



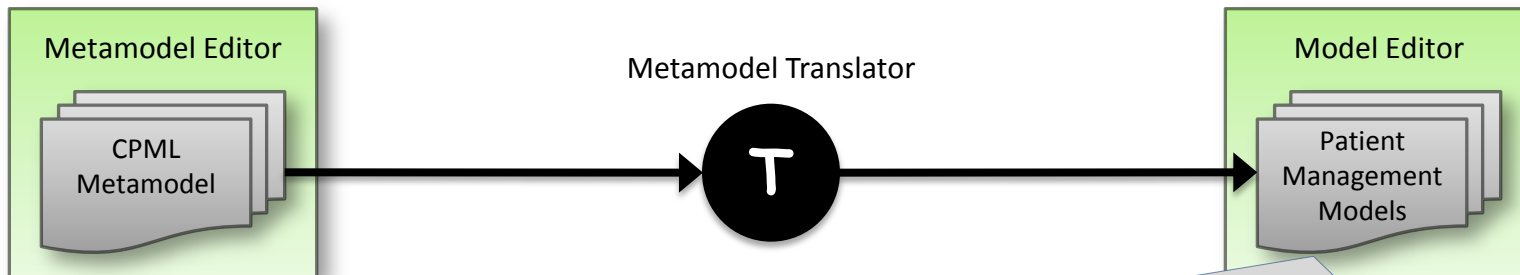


# Inside the Modeling Environment 8/9





# Inside the Modeling Environment 9/9



The screenshot shows the user interface of the modeling environment. It features several panels and a central workflow area:

- Diagnostics Panel:** Contains a circular icon with four arrows (yellow, blue, red, green) and a list of diagnostic tests: Blood Culture, CBC & diff. & Platelets, Sputum Culture, Blood Type & Screen, Lactate, Urinalysis, BMP, PT, PTT, INR, and Urine Culture.
- Therapeutics Panel:** Contains a circular icon with four arrows (yellow, blue, red, green) and a list of therapeutic options: Therapeutics, Septic Shock Rx, Early Goal-Directed Therapy, and Prophylaxis.
- Confirmation Dialog:** A dialog box titled "Diagnostics" with the question "Confirm computer diagnosis?". It has two buttons: "No" (with a "Select reason" dropdown) and "Yes" (with a "Hide treatment" button).
- Diagnostics orderables Panel:** A panel titled "Diagnostics orderables" with a "Diagnostics order" section containing a list of tests with checkboxes: BMP, Blood Culture, Blood Type & Screen, CBC & diff. & Platelets, Lactate, PT, PTT, INR, Sputum Culture, Urinalysis, and Urine Culture. Below this list is an "Add to order summary" button.
- Source control Panel:** A panel titled "Source control" with a dropdown menu and a question mark icon.

A large blue arrow points from the diagnostic tests in the left panel towards the "Diagnostics orderables" panel, indicating the flow of information.

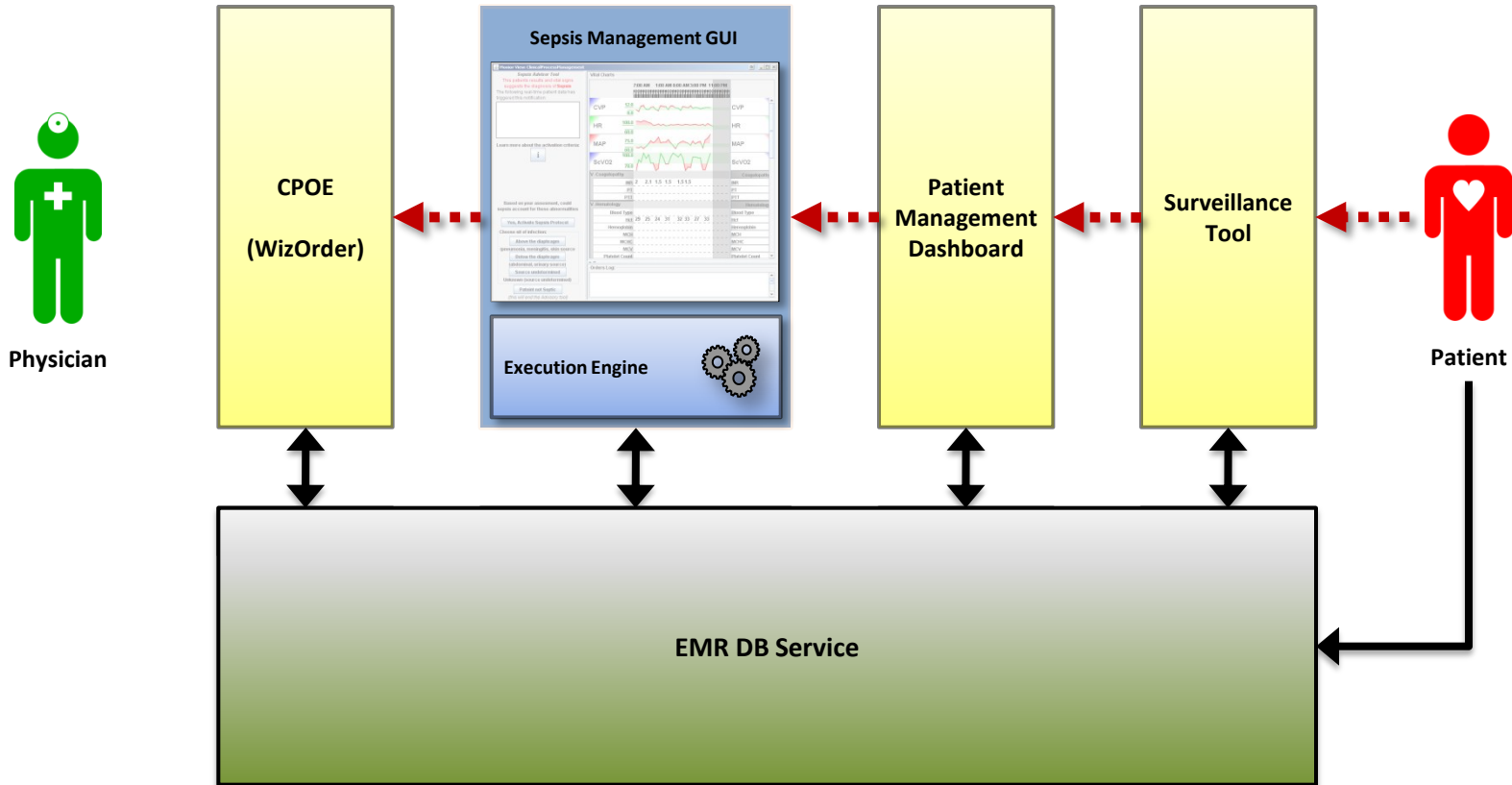


- 1. Principles**
- 2. Protocol modeling language for a sepsis management**
- 3. Engine for Model-integrated patient management and decision support systems**





# Introduction to the CPM GUI and Execution Engine



1. The Layout of the CPM User Interface
2. The Anatomy of the CPM Runtime (Execution Engine)
3. Execution Semantic of the Runtime (Execution Engine)



# Layout of the CPM User Interface

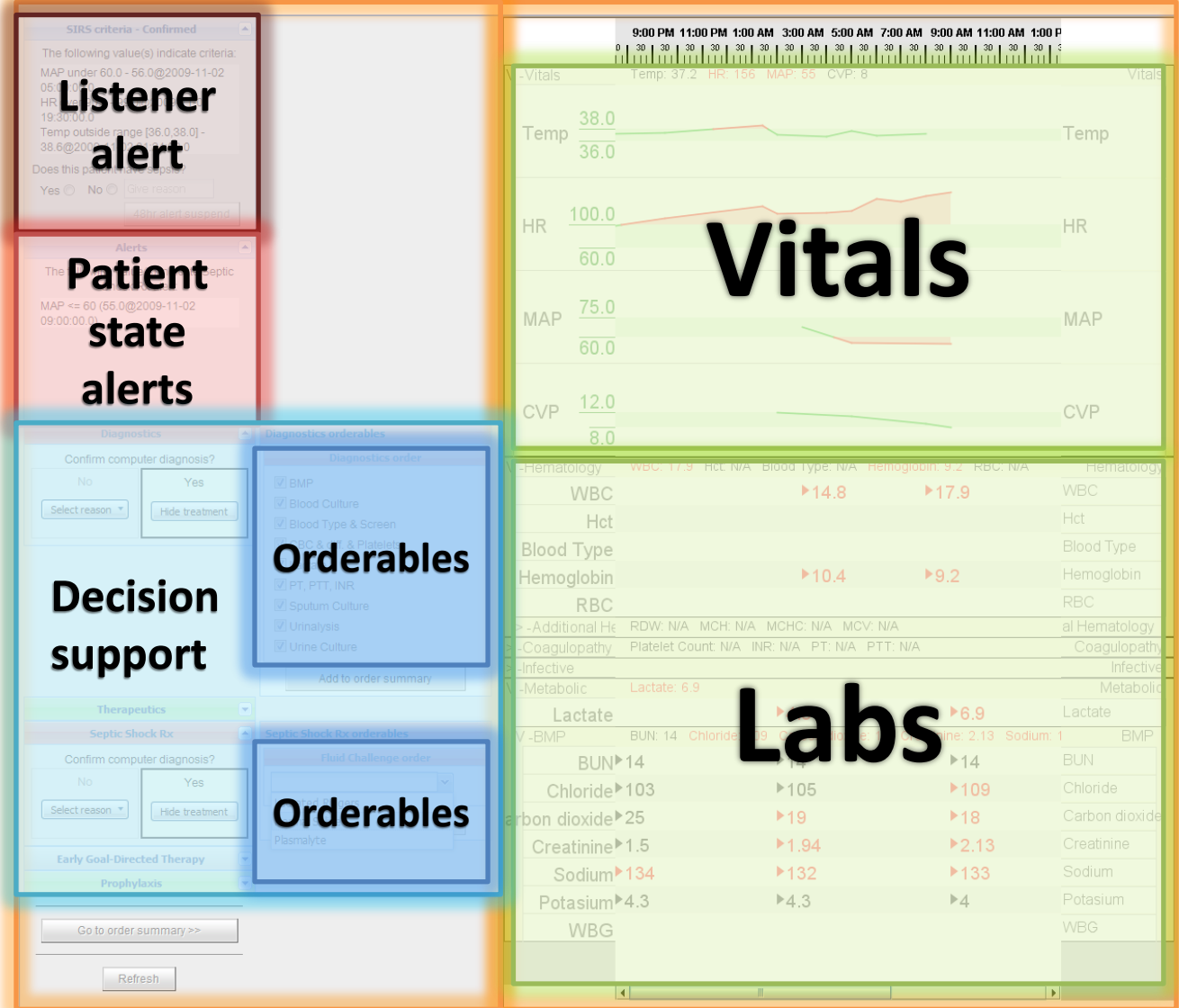


## Protocol View

## Patient View

Provides guideline based decision support in the context of the patient

1. Patient View – shows patient health status
2. Protocol View – shows status of the personalized protocol
3. Patient Alerts - helps situation awareness
4. Listener and Orderables - Integration into Clinical workflow





# Anatomy of the CPM Runtime



## Protocol View

Patient View

## Patient View

### Protocol Models

### GME

Vitals

V

Labs

CPML Translator

Runtime Configuration

The image displays several overlapping software windows:

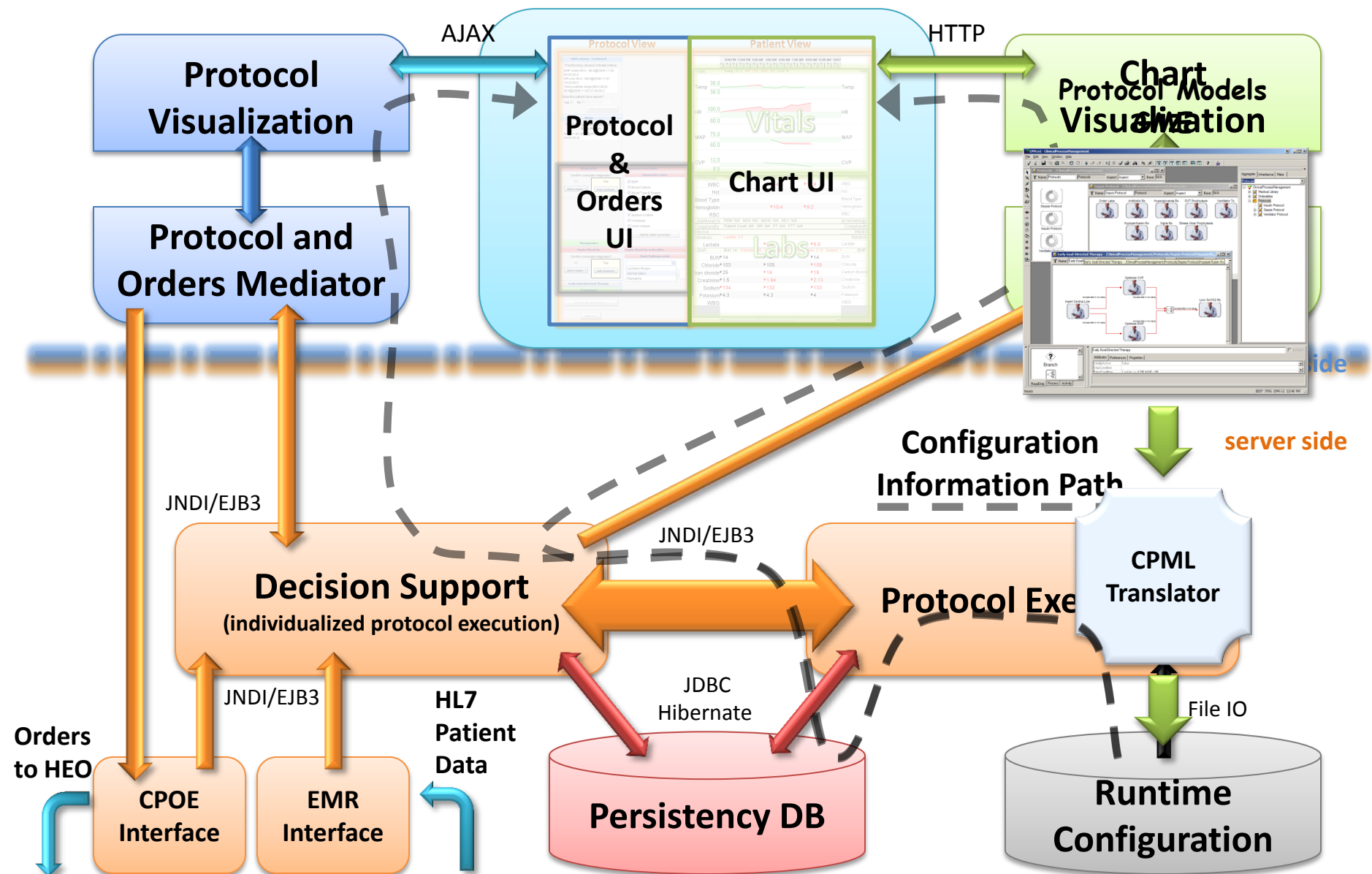
- Protocol View (Left):** Shows 'SIRS criteria - Confirmed' with a list of values (MAP, HR, Temp) and a 'Does this patient have sepsis?' question with 'Yes' and 'No' options.
- Patient View (Top Middle):** Features a 'Vitals' graph showing temperature, heart rate, and MAP over time, and a 'Labs' table with values for WBC, Hct, Hemoglobin, etc.
- Patient View (Right):** Shows a 'Protocol Models' window with a 'GME' (Goal Management Engine) interface, including a timeline and various icons.
- Diagnosis and Orderables (Bottom Left):** A 'Diagnostics' window with 'Confirm computer diagnosis?' buttons and a 'Diagnostics orderables' list including BMP, Blood Culture, CBC & diff., Lactate, PT, PTT, INR, Urinalysis, and Urine Culture.
- Lab Results (Bottom Middle):** A table of lab values such as WBC (14.8), Hemoglobin (10.4), Lactate (6.9), BUN (14), Chloride (103), Creatinine (1.5), Sodium (134), and Potassium (4.3).
- CPML Translator (Bottom Right):** A blue box with a green arrow pointing from the lab results to the 'Runtime Configuration' cylinder.

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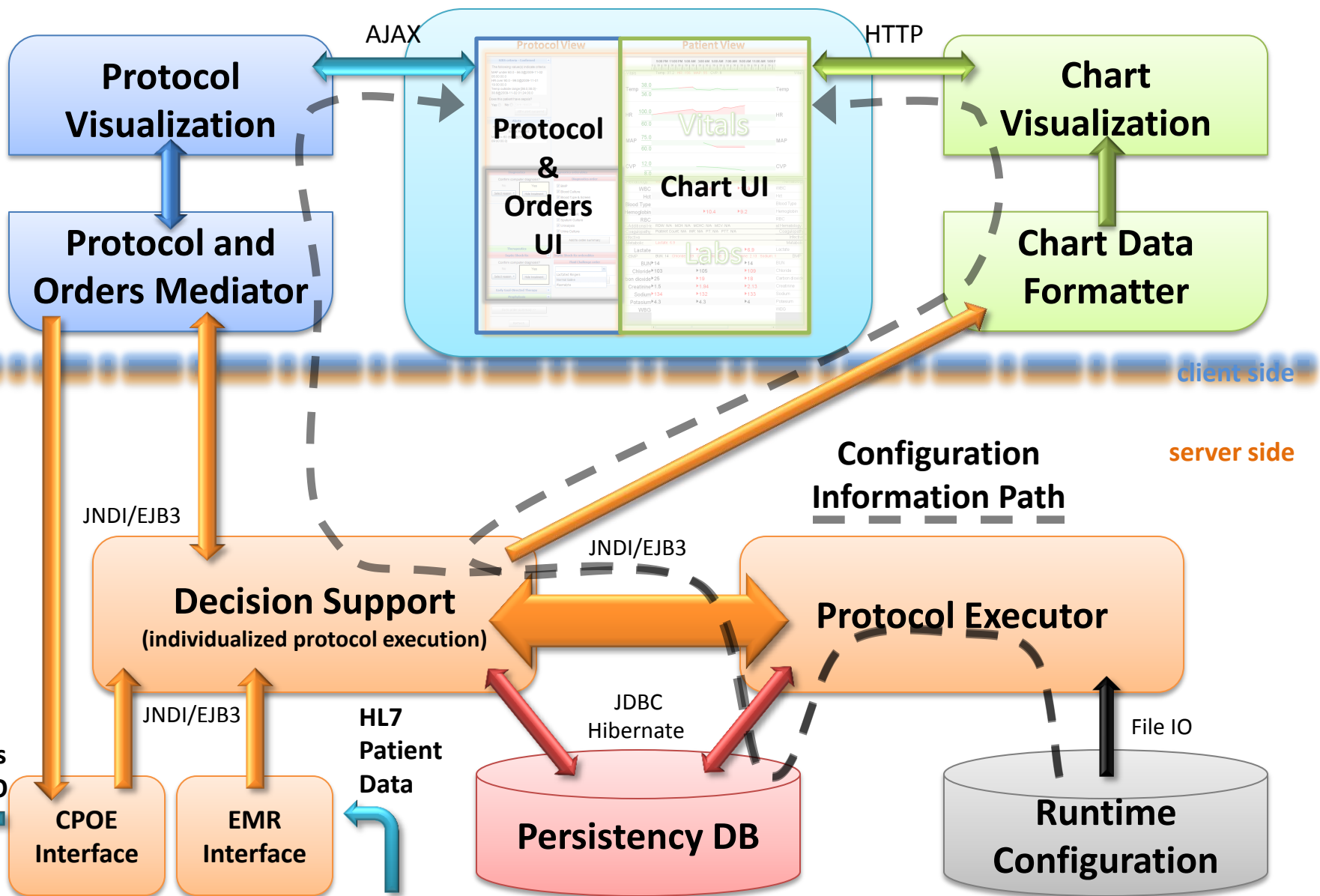


# Anatomy of the CPM Runtime



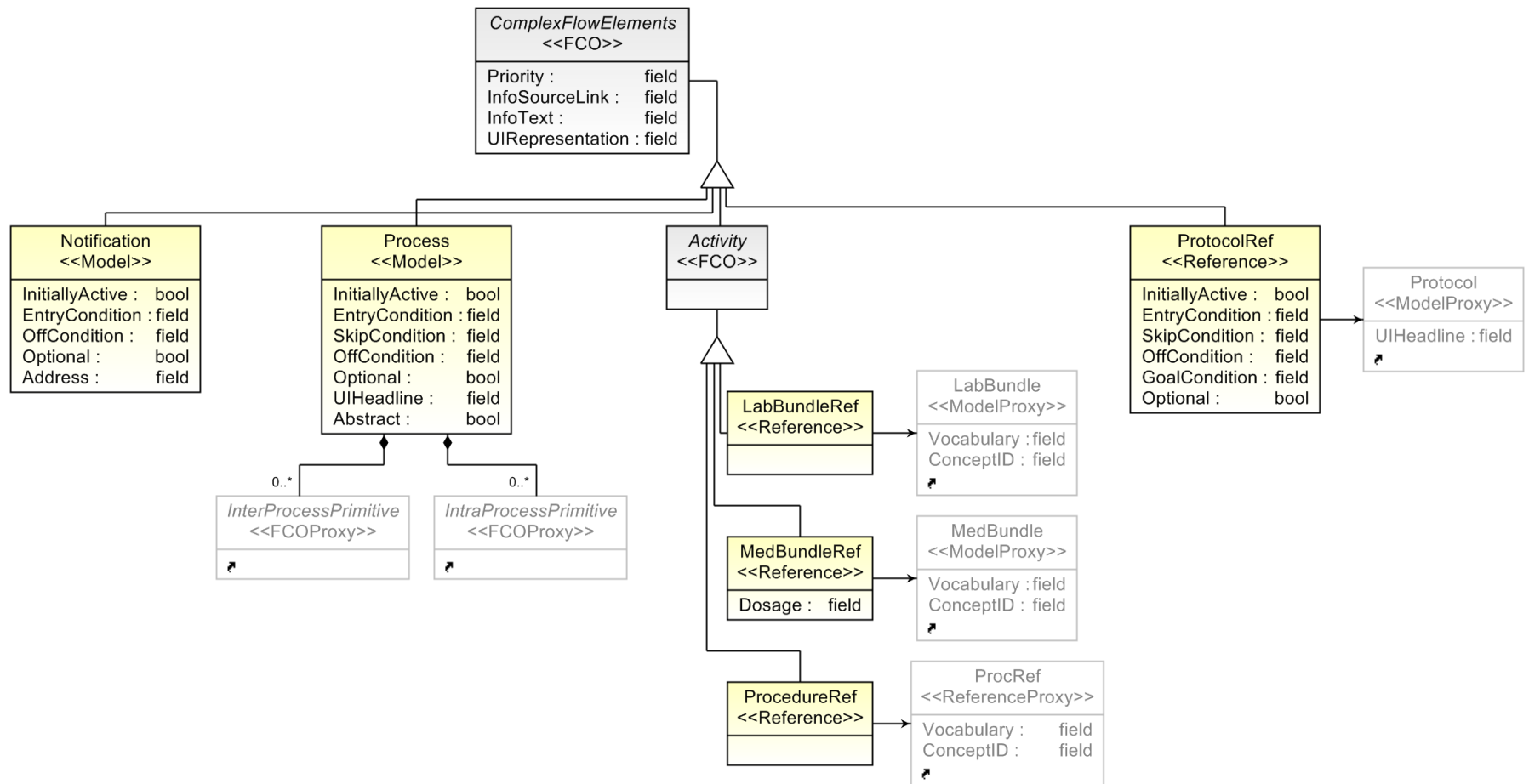


# Protocol Engine Semantics





# Protocol Engine Semantics



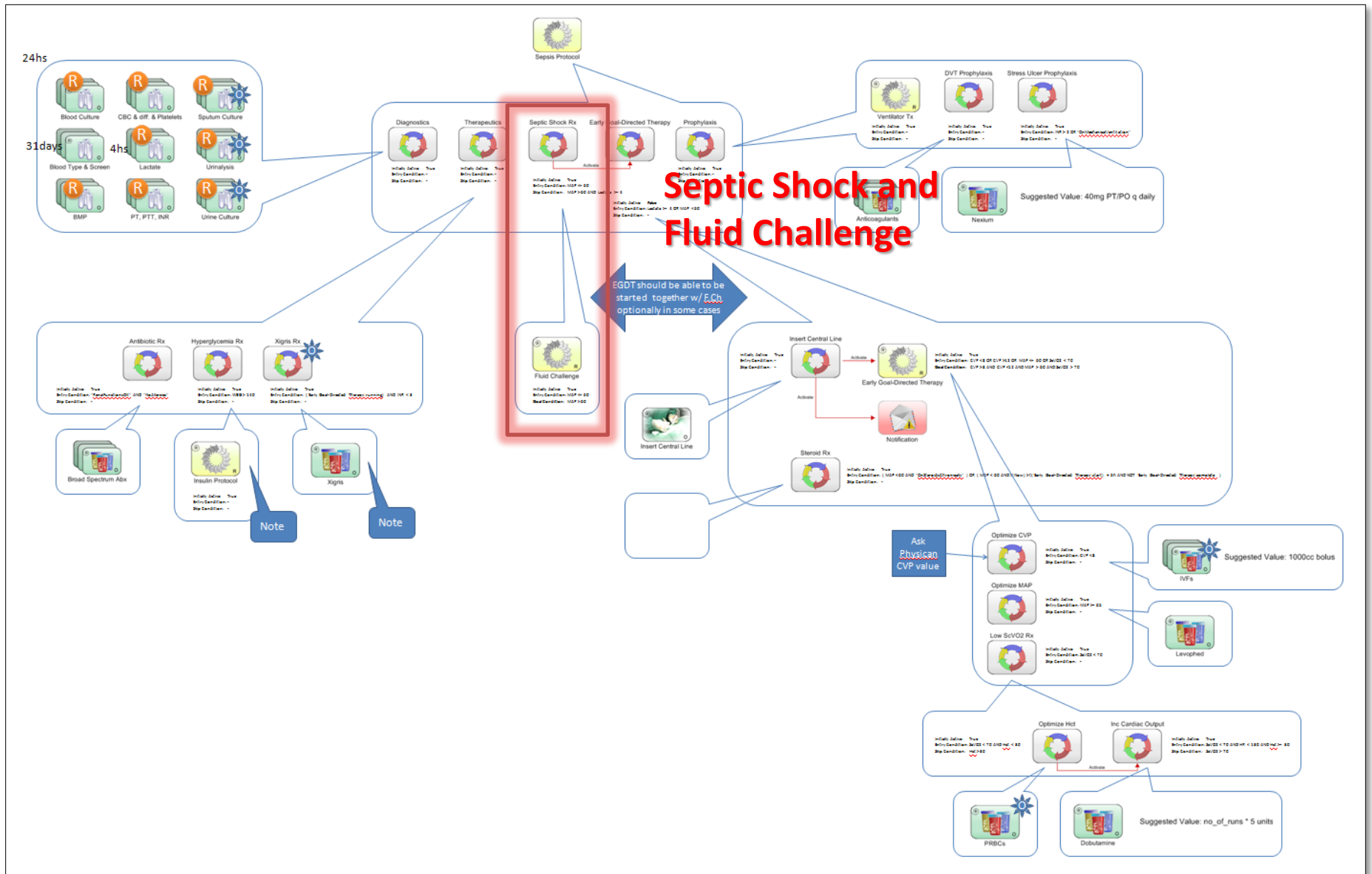
**Decision Support**  
(individualized protocol execution)



**Protocol Executor**



# Example: Fluid Challenge in Septic Shock





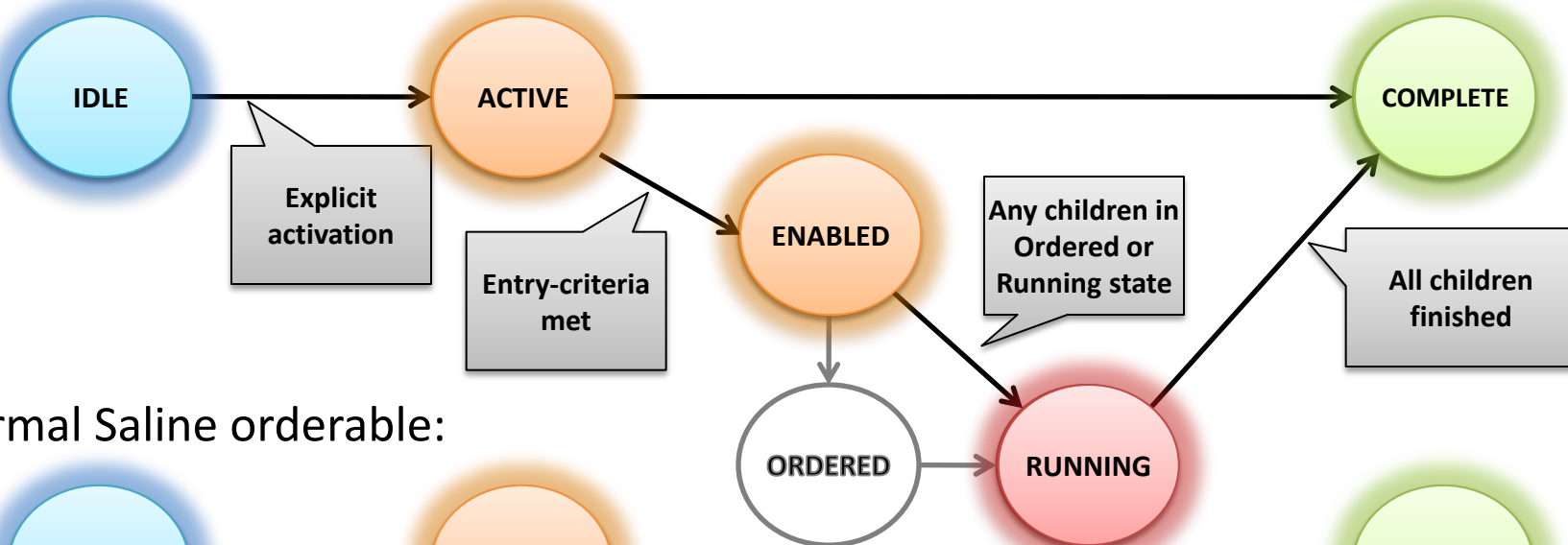


# Example:

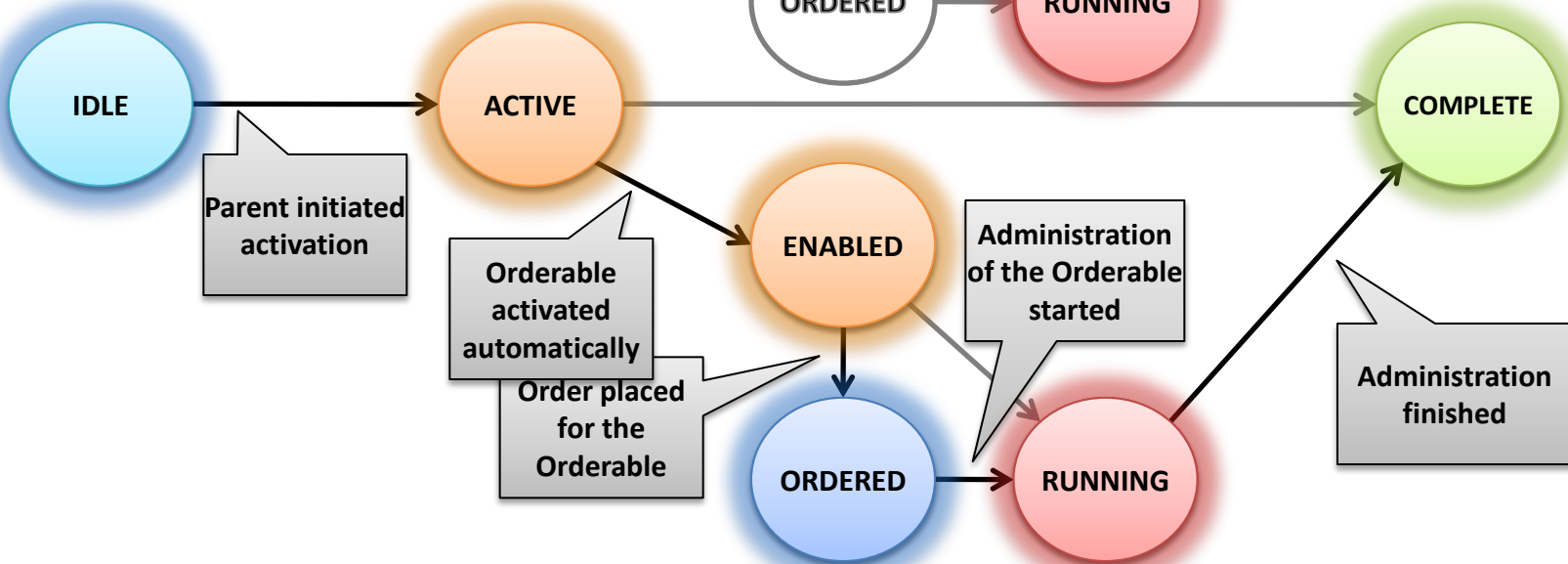
## Fluid Challenge in Septic Shock



Fluid Challenge process: Entry-criteria MAP < 60



Normal Saline orderable:







**Thank You**



Questions?