

PHware for remote risk awareness of COVID-19 outpatients' condition during homecare:

Verifying functional integration of patient, provider & AI

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Why BPMN to Design HIT?

People use and change data in clinical healthcare-

- Failure to include both people & computers as a joint team leaves important parts of HIT systems to chance and risks patient safety
- BPMN has explicit representations of people's activity and computing to design their functional integration.

Demo Objective

Show how the Shared Data Model of the BPM+ Field Guide can specify semantics of *risk awareness* as a computationally independent model (CIM) for-

- Functional integration of people and computing for remote patient monitoring
- Verification of design correctness prior to deployment

Clinical Care Problem (COVID-19 may not be done with us, yet)

Clinicians' dilemma when patients with mild symptoms test positive for COVID-19:

- Admission for observation takes beds from more severe cases while risking transmission;
 - But ordering homecare risks outpatient deterioration faster than providers can become aware.
 - Existing systems for remote patient monitoring (RPM) are relatively slow, require dedicated attention by scarce clinical personnel, and require outpatients to use multiple expensive devices.
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Functional RPM Requirement ([O1 link](#))

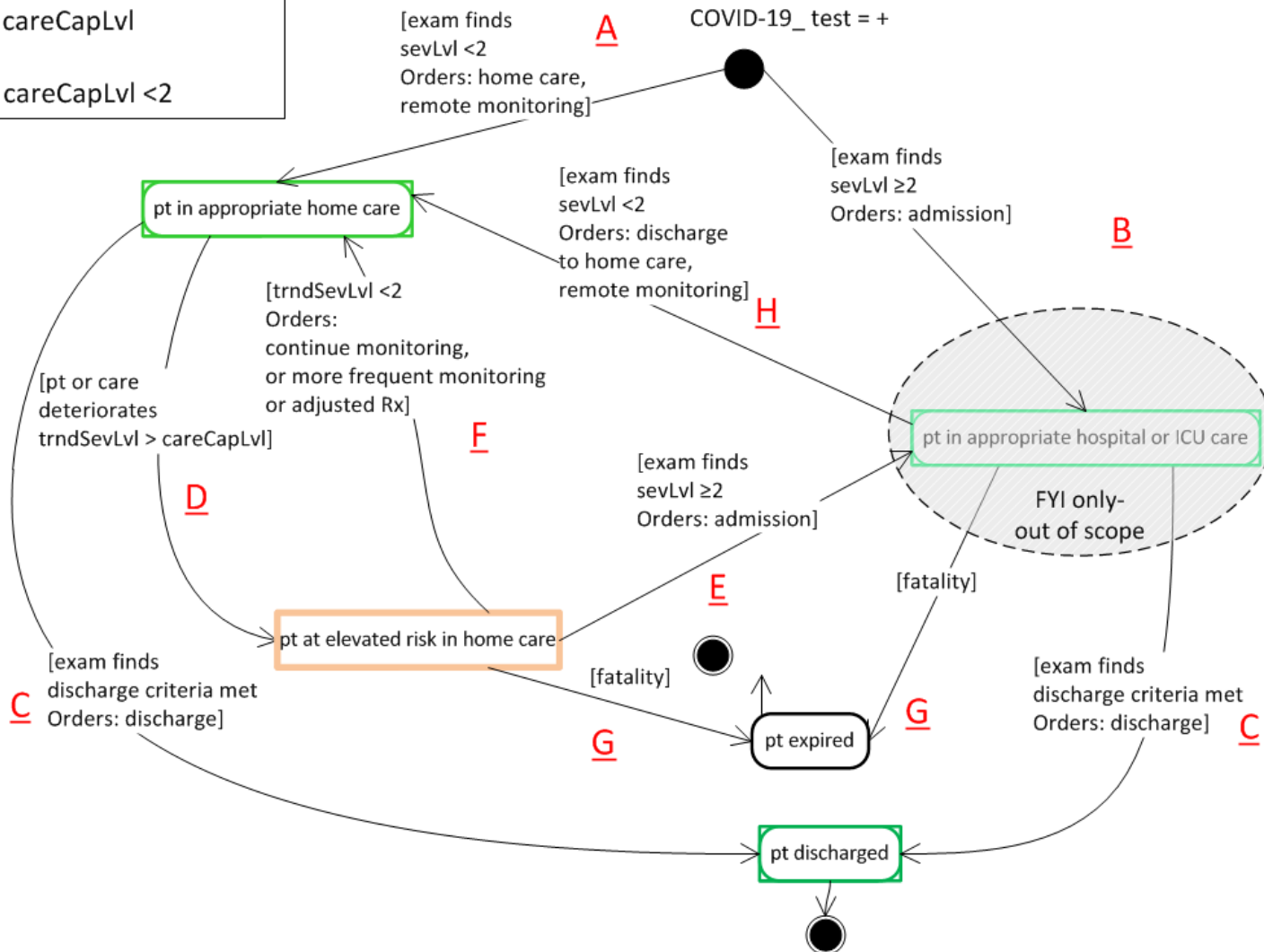
The functional purpose of RPM is to provide clinicians with *actionable risk awareness*.

- Abstract and needs more than intuition or common sense to define it
 - We adapted Medicare 4-point severity-of-illness DRG ratings to model the severity level of patient condition and the needed level of care.
 - Severity level <2 is mild and home care capability level <2 is typically appropriate
 - We defined *elevated outpatient risk* from home care as the inequality:
 - *Severity Level > Home Care Capability Level*
 - or
 - *TrendingSeverityLevel > Home Care Capability Level*
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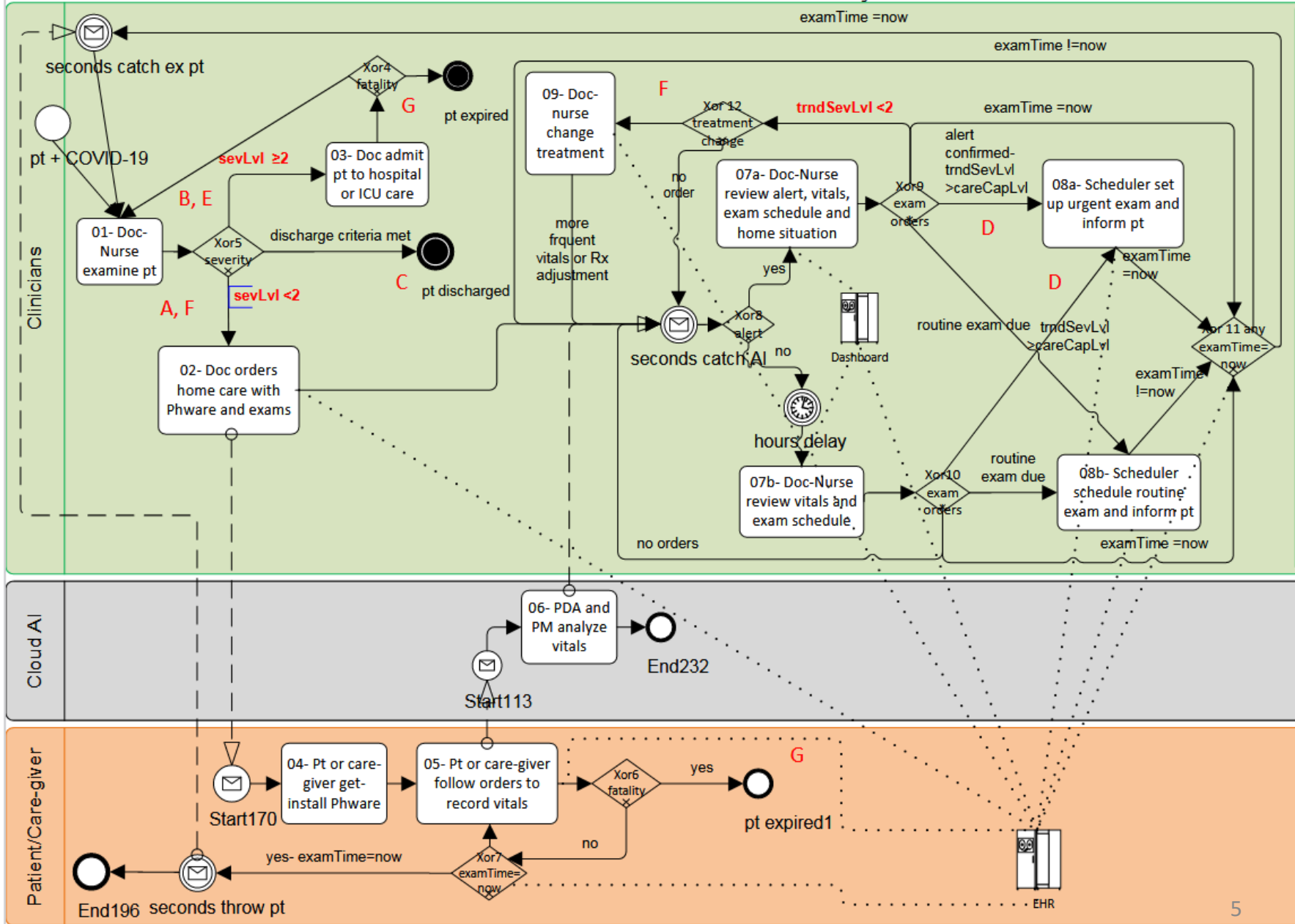
Risk Awareness: Computationally Independent Model

Assumptions:

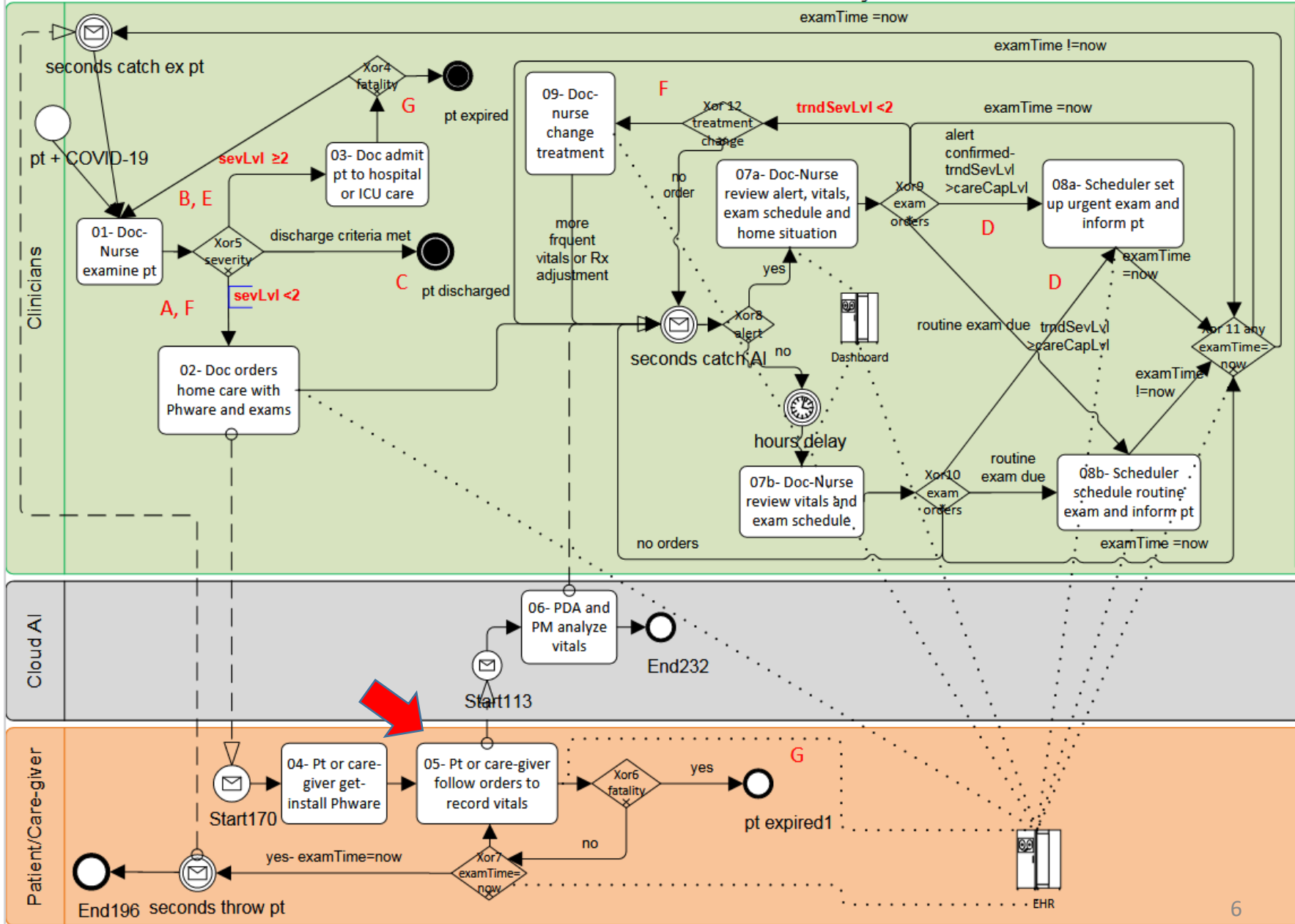
- Patient at elevated risk when $sevLvl \geq careCapLvl$
or
 $trndSevLvl \geq careCapLvl$
- Initial home $careCapLvl < 2$



PHware RPM of Vital Signs for COVID-19 Outpatients



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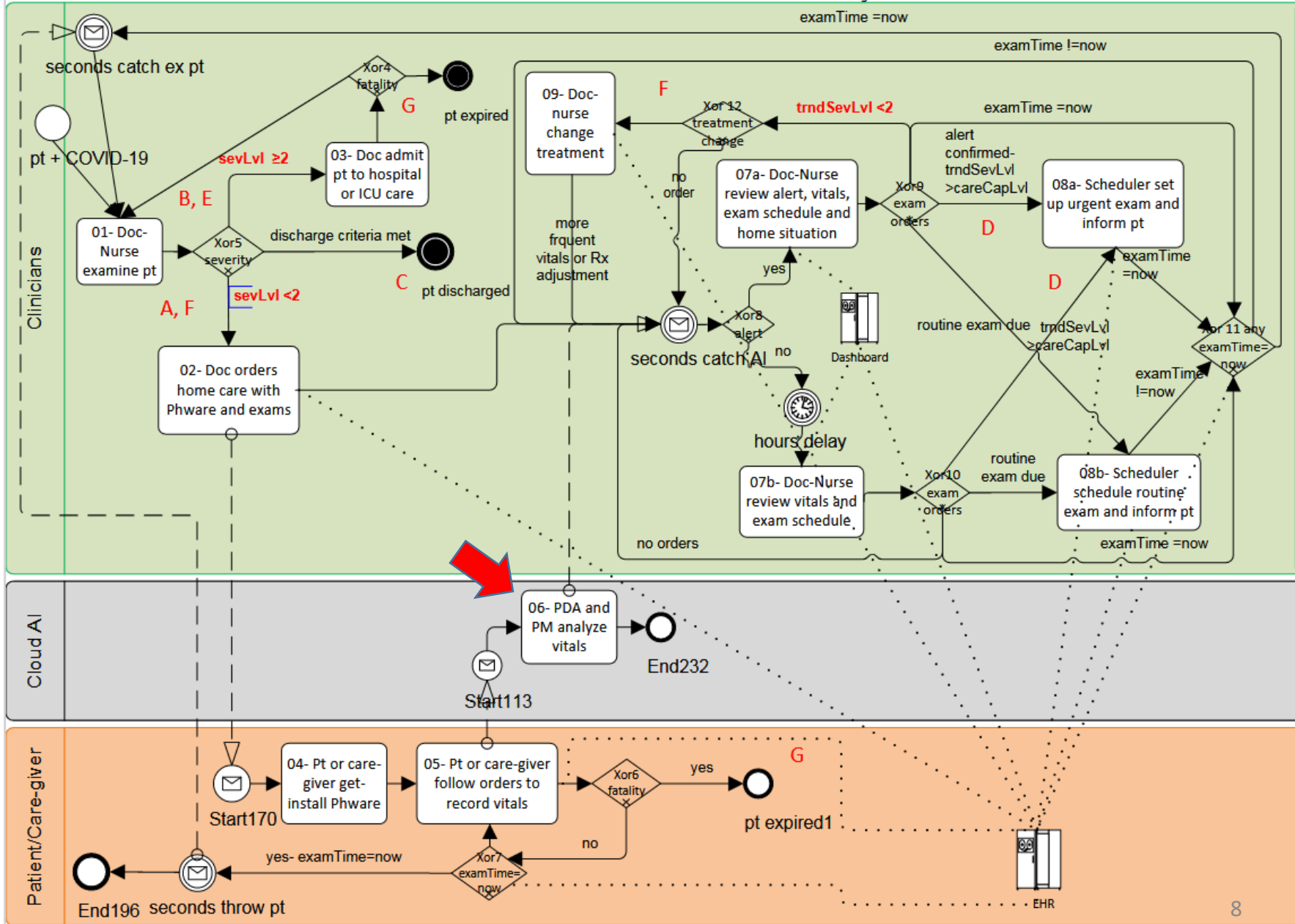
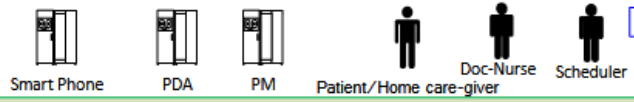


Workflow of *PHware*© for RPM (select [link to 05](#))

- Replaces multiple devices with a single, inexpensive, noninvasive finger-clip
- Senses data of 7 vital signs at home within a single 60-90 second session.
- Smart phone uploads sensor data to AI Server



PHware RPM of Vital Signs for COVID-19 Outpatients



End196 seconds throw pt

EHR

Cloud AI Server ([link to 06](#))

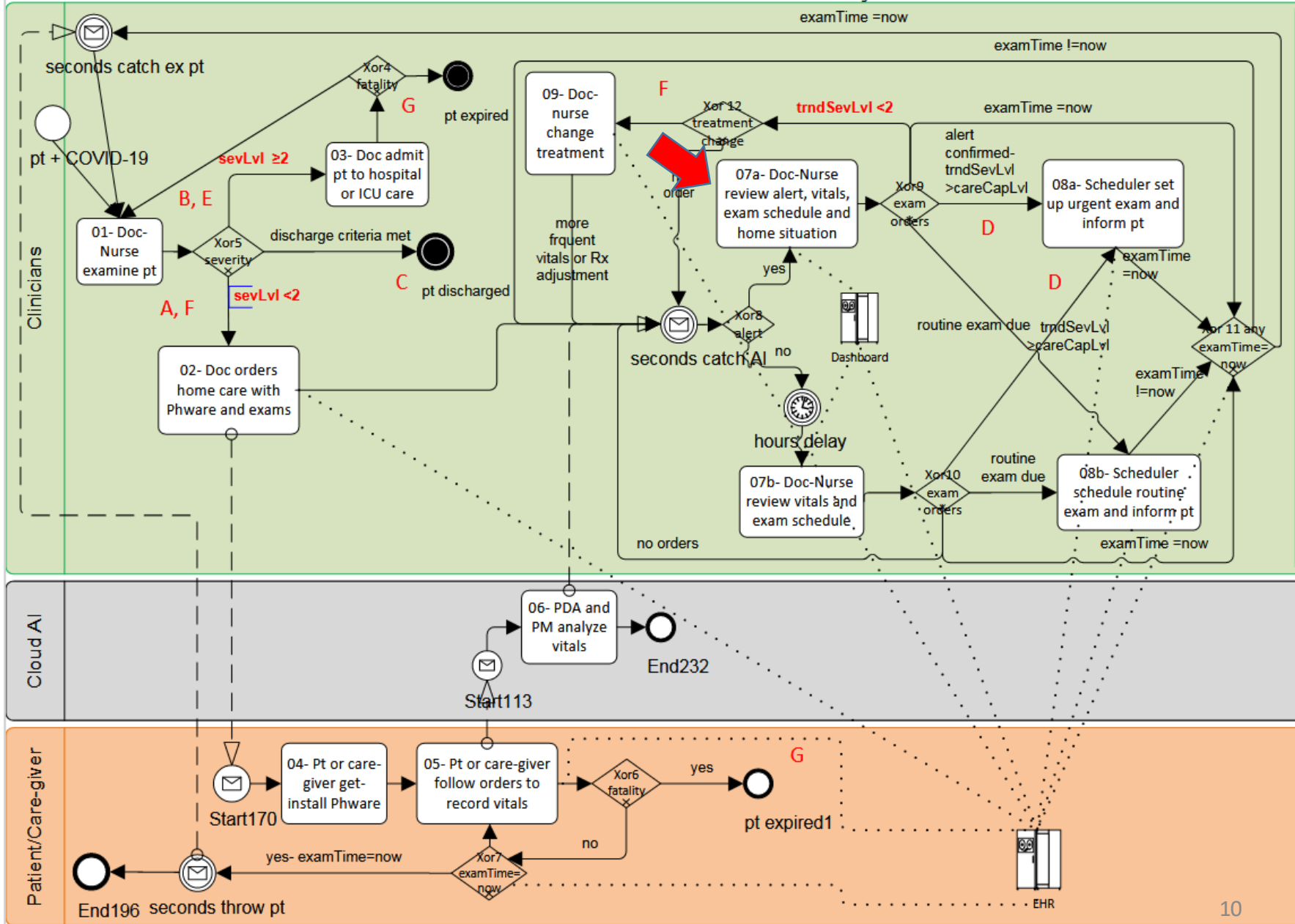
Exploits Power of cloud computing-

- Personal Data Analyzer with machine learning assigns numerical vital sign values to sensed data
- Preliminary accuracy evaluation reached levels needed for medical use for:
 - oxygen saturation
 - respiration rate
 - temperature
 - heart rate/variability
 - sys/diastolic blood pressures

Predictive Model under development to calculate severity trends

- Throws alert if –
 - *Severity Level > Home Care Capability Level*
 - or
 - *TrendingSeverityLevel > Home Care Capability Level*
-

PHware RPM of Vital Signs for COVID-19 Outpatients



Upper right models provider decision authority

- If AI sends an alert it by-passes the ordinary delay for providers to check the dashboard.
- Relationship between clinician and AI
 - AI alerts recommend to providers which patients need urgent attention
- ([select link to 07a](#))
 - The home page User interface is based on cognitive strategy of management-by- exception
 - Patients with alerts are moved to the top of a sortable list
 - The specialized web dashboard gives providers timely *risk awareness* and actionable decision support.
- **Select** [Amberly DeLong](#) on Home Page (or click [here](#))
- One click displays vital signs of the alert
 - Shows blood O2 dropping and respiration rate going up
- If an alert is confirmed the scheduler in 08a sets up an urgent exam that is augmented by realtime vitals

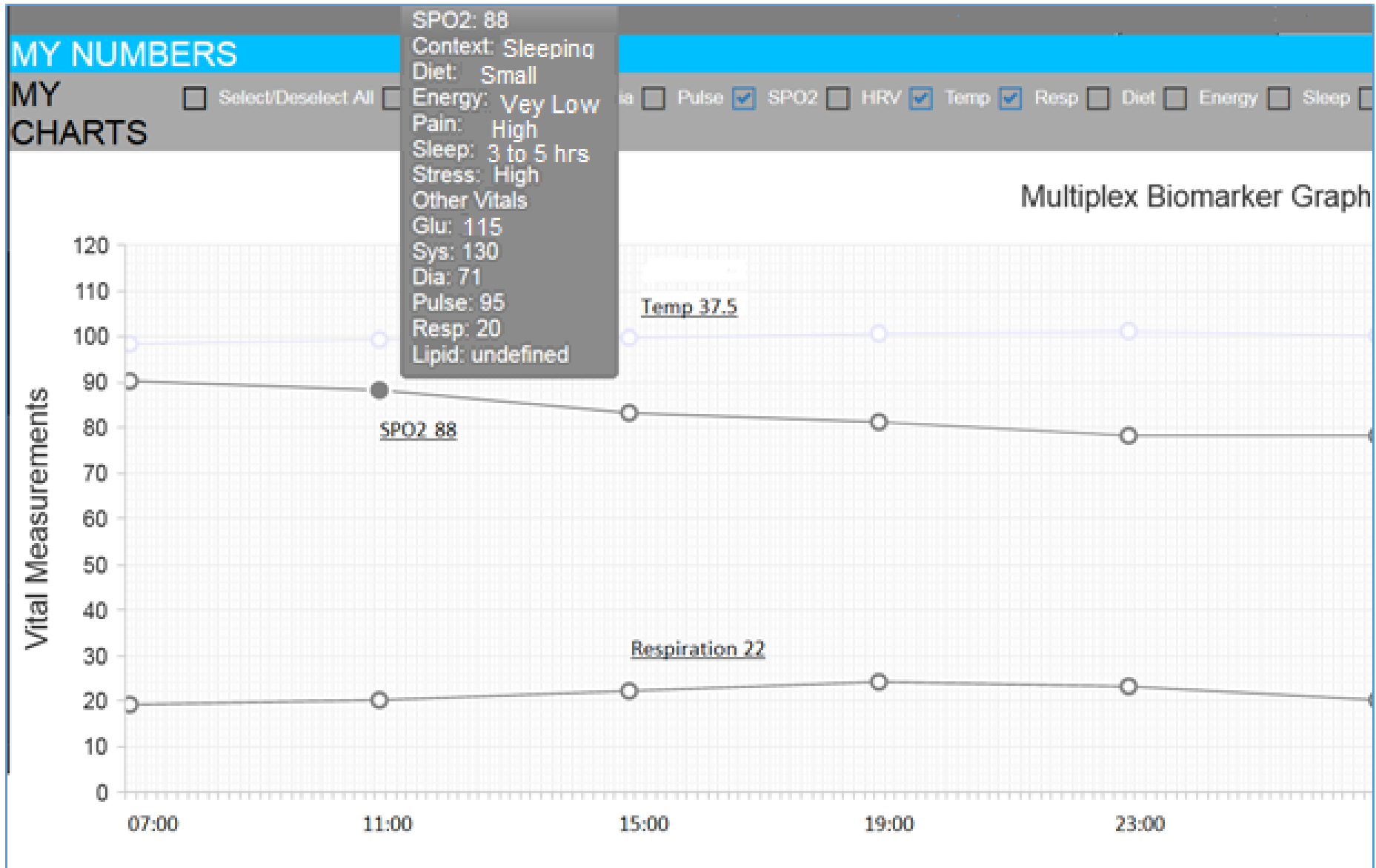
Authority for medical decision-making is preserved for providers

- But reasons the clinician may override alert
 - an exam already scheduled for today
 - more severe patients in queue

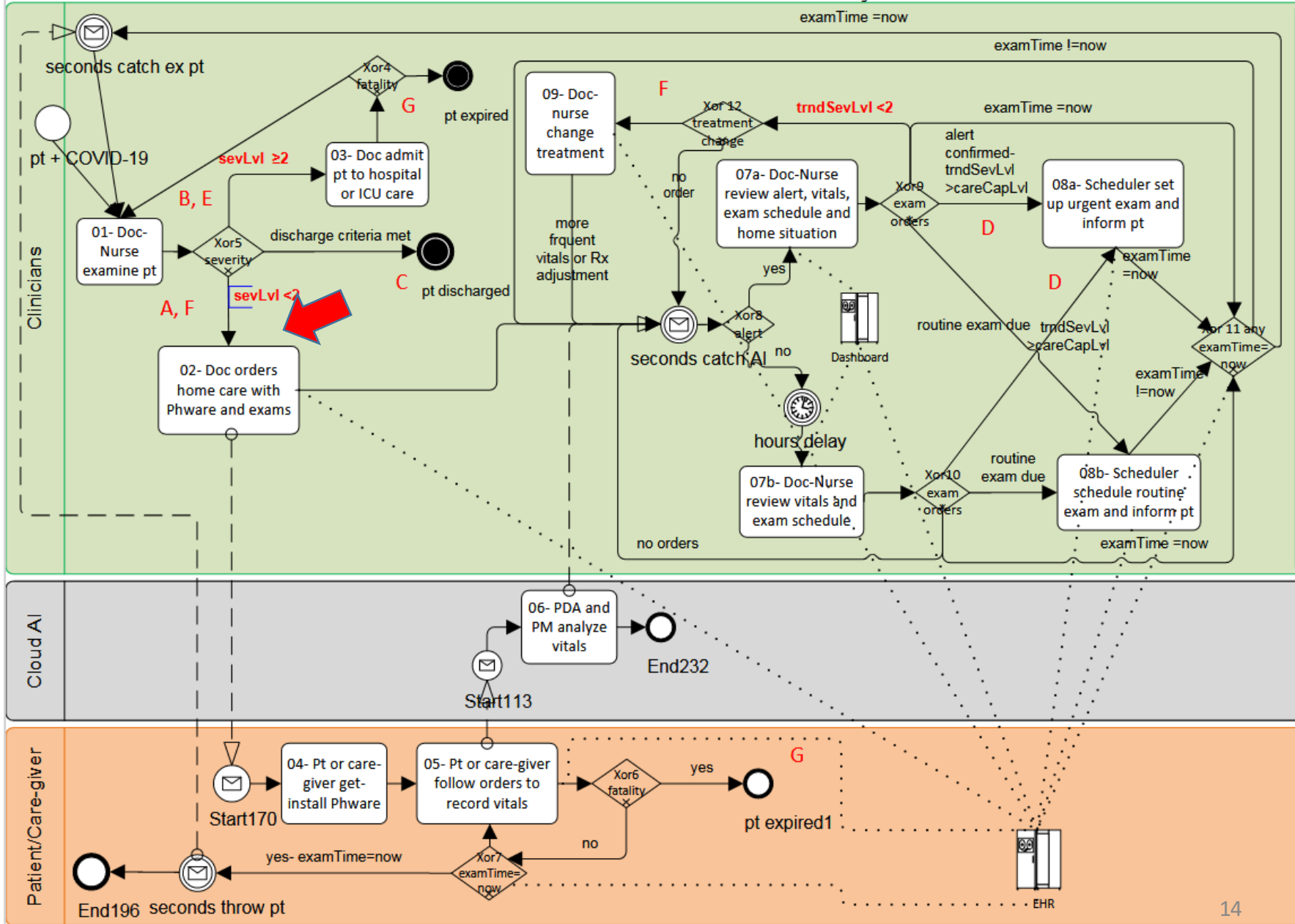
The Dashboard's home page is a sortable list of patients

Home- Outpatient Management					
Name	Severity	Last Exam	Next Exam		Smart Phone#
Amberly DeLong MRN#123456789 1955-11-22 60	1	2/1/21	2/8/21	15:00	2065551212
Elliot Marlowe MRN#123456789 1969-04-15 52	1	2/7/21	2/14/21	14:00	2065551213
Guadalupe MRN#123456789 1970-10-22 50	2	2/5/21	2/12/21	8:30	2065551214
Dennis Hare MRN#123456789 1980-9-20 40	1	2/2/21	2/9/21	9:00	2065551215
Carl Jennings MRN#123456789 1985-9-22 35	2	2/7/21	2/14/21	13:30	2065551216
Robert Jones MRN123456789 1981-1-23 41	2	2/3/21	2/10/21	8:30	2065551217
Kevin Keller MRN123456789 1977-11-3 44	2	2/5/21	2/13/21	13:30	2065551218
Cedric Palmer MRN#123456789 1999-6-28 20	1	2/3/21	2/10/21	9:30	2065551219
Mildred Stevens MRN#123456789 1972-7-26 39	2	1/31/21	2/7/21	8:30	2065551223
Gerald Teller MRN#123456789	1	2/4/21	2/11/21	15:30	2065551221

The trend of vitals is 1-click away



PHware RPM of Vital Signs for COVID-19 Outpatients



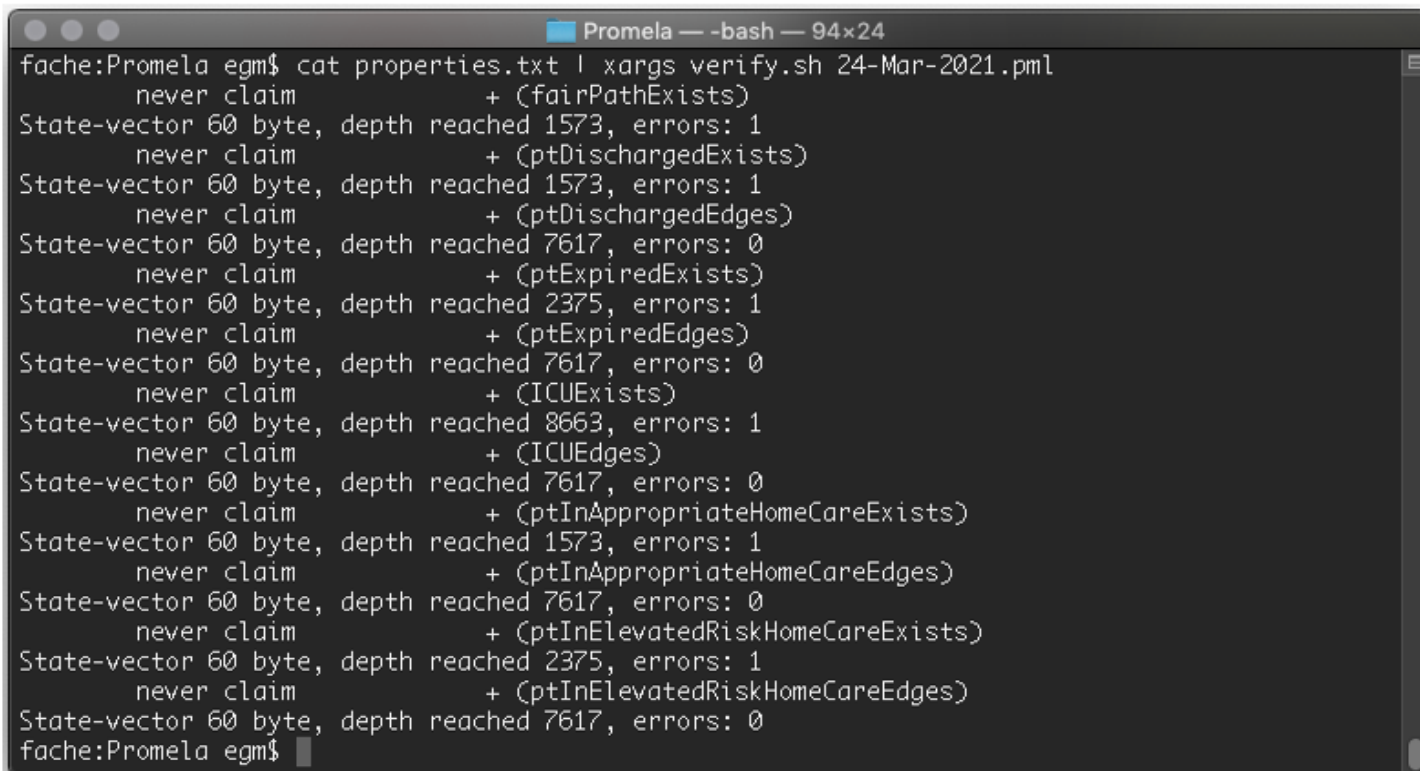
Model-Checking Integrated Design Correctness (Xor11 link)

Functionally integrated workflow is remote, asynchronous, & abstract

- Accurate performance is critical for patient safety

Model-checking was invented to prove whether system designs are correct


- The technology achievement of *The 2007 ACM Turing Award*
- The risk awareness CIM is a system property that allows us to extend model-checking to PHware's joint human-computing system
- BPMN was translated into Promela, and the SPIN model-checker used a logically equivalent version of the CIM as the property to verify
- The SPIN results below prove the integrated BPMN design is correct to establish and maintain risk awareness in all its states and sequences.



```
Promela — -bash — 94x24
fache:Promela egm$ cat properties.txt | xargs verify.sh 24-Mar-2021.pml
  never claim          + (fairPathExists)
State-vector 60 byte, depth reached 1573, errors: 1
  never claim          + (ptDischargedExists)
State-vector 60 byte, depth reached 1573, errors: 1
  never claim          + (ptDischargedEdges)
State-vector 60 byte, depth reached 7617, errors: 0
  never claim          + (ptExpiredExists)
State-vector 60 byte, depth reached 2375, errors: 1
  never claim          + (ptExpiredEdges)
State-vector 60 byte, depth reached 7617, errors: 0
  never claim          + (ICUExists)
State-vector 60 byte, depth reached 8663, errors: 1
  never claim          + (ICUEdges)
State-vector 60 byte, depth reached 7617, errors: 0
  never claim          + (ptInAppropriateHomeCareExists)
State-vector 60 byte, depth reached 1573, errors: 1
  never claim          + (ptInAppropriateHomeCareEdges)
State-vector 60 byte, depth reached 7617, errors: 0
  never claim          + (ptInElevatedRiskHomeCareExists)
State-vector 60 byte, depth reached 2375, errors: 1
  never claim          + (ptInElevatedRiskHomeCareEdges)
State-vector 60 byte, depth reached 7617, errors: 0
fache:Promela egm$
```

Conclusions (EHR link)

BPMN is more powerful with The Shared Data Model of the BPM+ Field Guide to specify the semantics of *risk awareness* as a CIM-

- PHware design enhances outpatient safety
 - Technology independence of the CIM allow  (Ctrl) rve as a well-defined, sharable work object
 - Functional integration of people and computing can be designed by coordinating their shared work on the common work object of the CIM
 - Also- CIM provides a new type of evaluation criterion to extend model-checking to prove the correctness of the functionally integrated workflow of people and computing.
 - BPMN has important potential as a design environment to enhance patient safety.
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Questions about-

- PHware – abahrami@bionous.com
 - CIM or BPMN workflow- kebutler@uw.edu
 - Model-check with Promela and SPIN- egm@cs.byu.edu
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