Emory University Hospital Emergency Department Patient Scheduling

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Emory University Hospital (EUH)

- Emory Healthcare System
- Leading national healthcare provider
- Patients:
  - Inpatients: 24,000/year
  - Outpatients: 80,000/year

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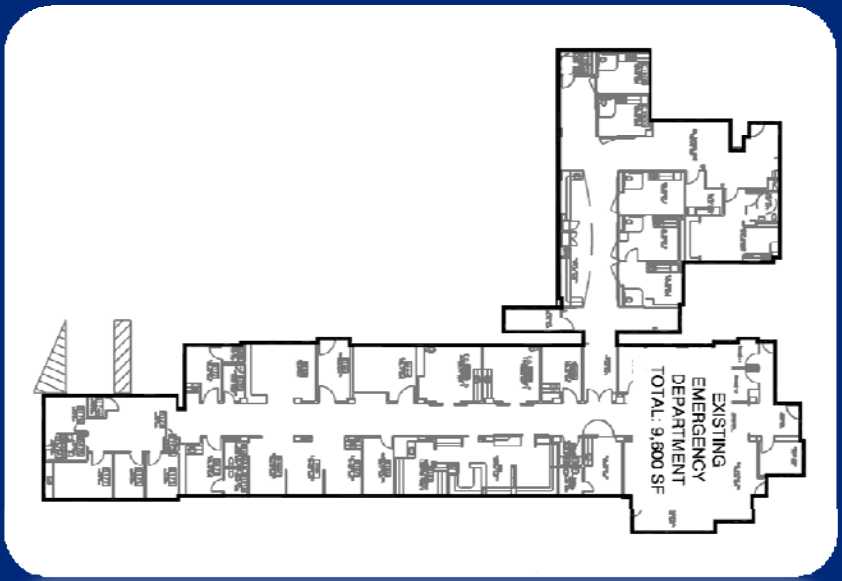
Emory University Hospital Emergency Department (EUH ED)

Patients:

- 32,850/year
- 90/day

Capacity:

- 21 rooms
- 8-10 hall spots



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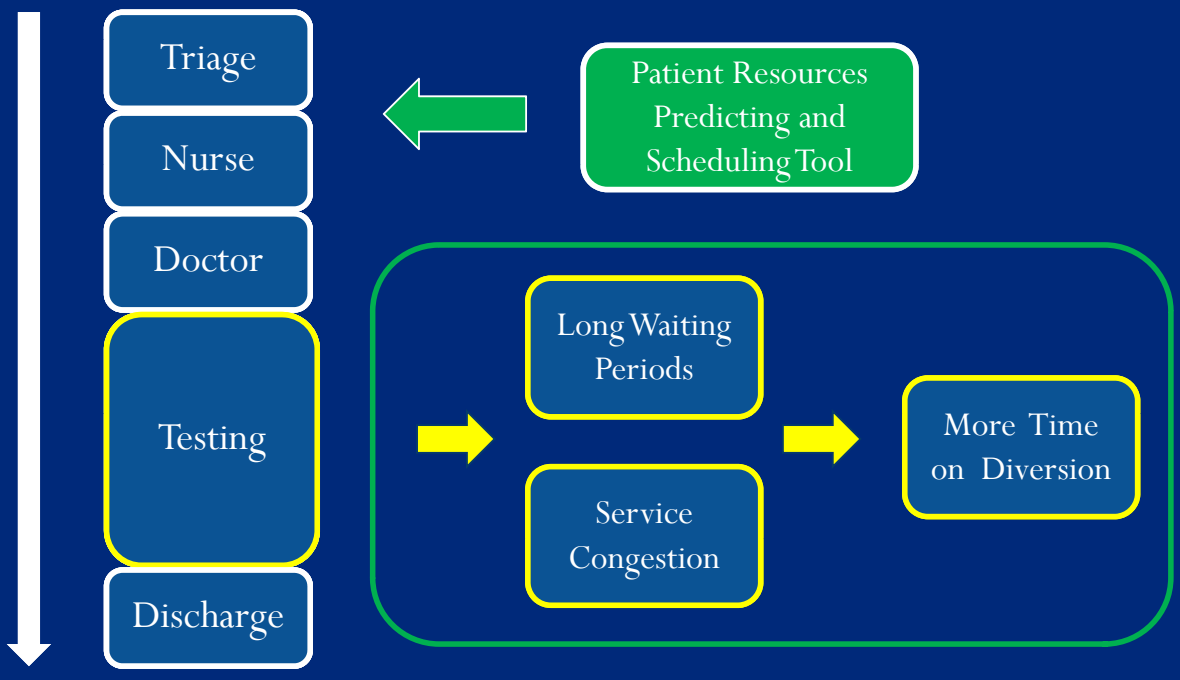
Project Motivation



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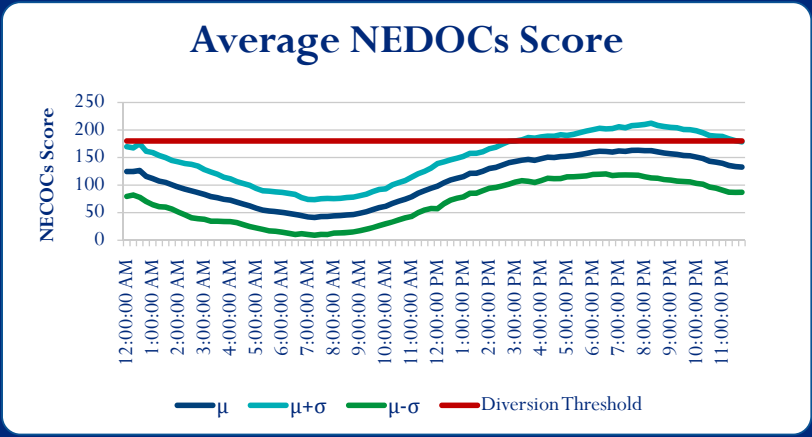
Diversion Score

0-20	21-60	61-100	101-140	141-180	181-200
Not busy	Busy	Extremely Busy, Not Over-Crowded	Over-Crowded	Severely Over-Crowded	Dangerously Over-Crowded



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Methodology Overview

Patient Resources Predicting and Scheduling Tool

- Predict Patient Resources
- Schedule Patients
  - Processing Times
  - Scheduling Algorithms

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Resources for Predicting and Scheduling

Radiology Tests	2009 Count
X-Ray	12,400
X-Ray Portable	7,400
CT w/ Contrast	4,100
CT w/o Contrast	6,500
Ultrasound	3,100
MRI	1,900
MRA	800

Other Tests	2009 Count
EKG	13,900
Urine Collect	15,400
Blood Draw	22,000

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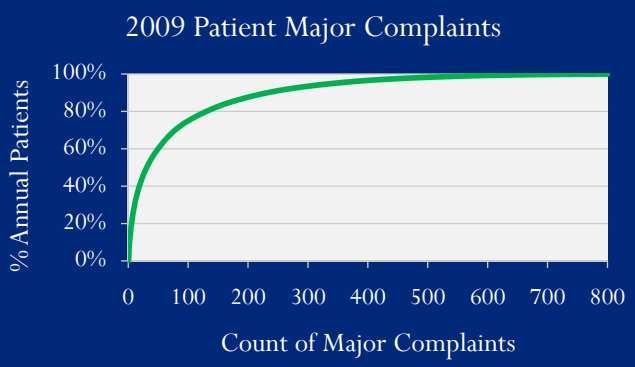
Predictors of Resource Requirements

Patient Acuity

1 Immediate 4%	2 Emergent 39%	3 Urgent 43%	4 Stable 14%	5 Non-Urgent 1%

Major Complaint

% Complaints	Count
70%	78
80%	131
90%	232
Total Complaints	**801**



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Probability of Requiring Resources

Probability of Needing an EKG				
	Acuity			
Major Complaint	**1**	**2**	**3**	**4**
Chest pain	1.00	0.99	0.97	0.83
Difficulty Breathing	0.97	0.90	0.67	0.40
Altered Mental Status	0.97	0.89	0.80	-
Syncope	1.00	0.97	0.90	1.00
Pain, Abd General	1.00	0.44	0.22	0.07

Determine Threshold

Expected # Adds = Expected # Deletes

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Determining Probability Threshold

Sensitivity
- True Positive Rate
- % of patients correctly predicted to require a test

Specificity
- True Negative Rate
- % of patients correctly predicted to NOT require a test

		Actual Condition: Test Needed	Actual Condition: Test Not Needed
Predicted Condition	Test Needed	True Positive	False Positive
	Test Not Needed	False Negative	True Negative

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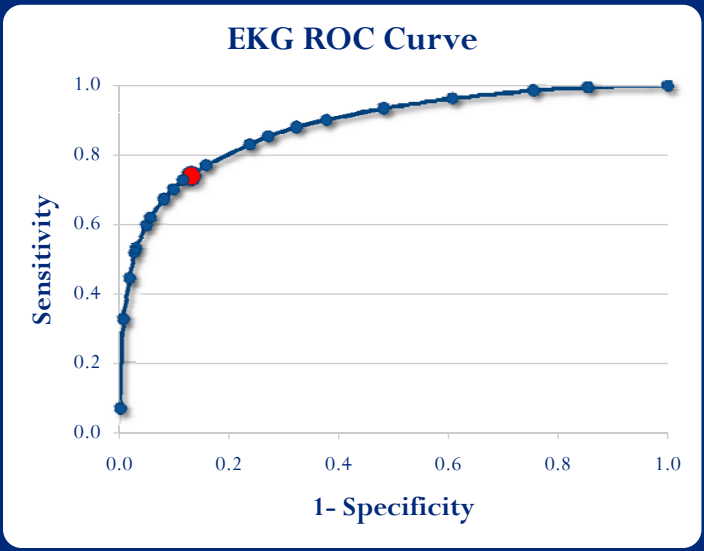
Receiver Operating Characteristic (ROC) Curves



Threshold	0.50
Sensitivity	0.74
Specificity	0.87

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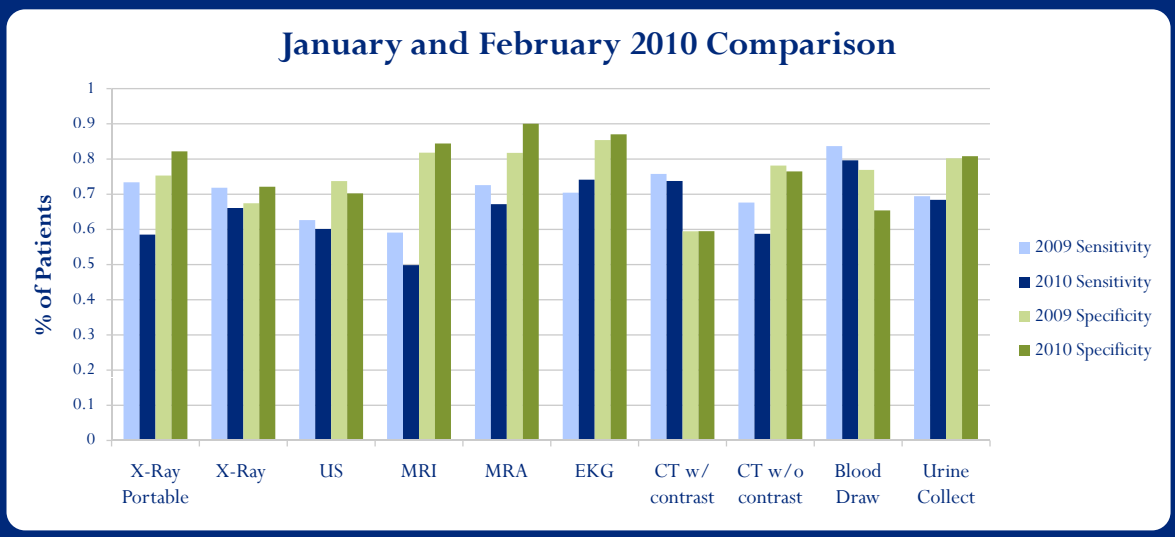
Testing Thresholds



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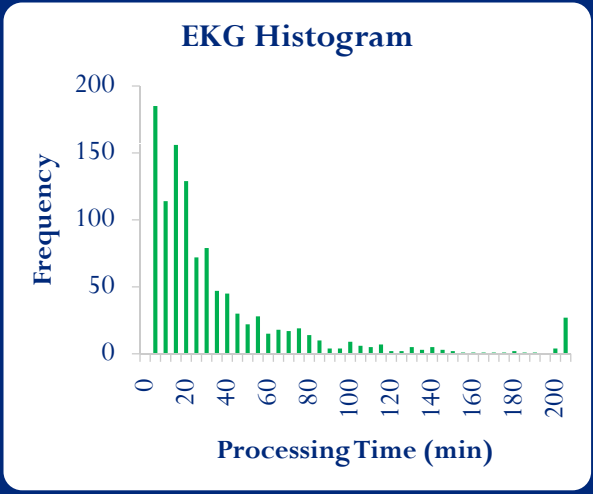
Processing Times



Test	Median	μ	σ
MRA	48	56	34
X-Ray Portable	18	42	36
X-Ray	14	31	59
Ultrasound	24	26	12
MRI	50	74	54
EKG	18	29	27
CT w/o Contrast	13	31	21
CT w/ Contrast	21	18	13

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OSCAR: Scheduling Tool

O perational

S cheduling of

C are

A nd

R esources

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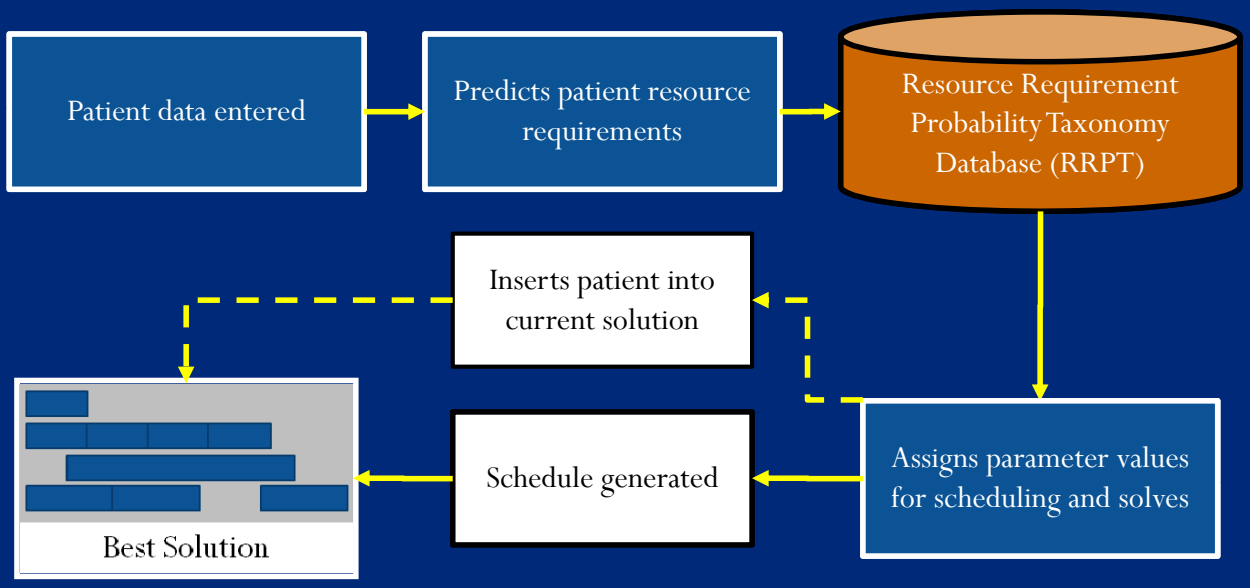
OSCAR: Scheduling Tool



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Solver Module Methodology

Objective

Minimize Length of Stay (LOS) for each patient

Inputs

Primary: Patient Name, Acuity, Major Complaint
Secondary: Doctor and Nurse Validation

Constraints

1 patient / resource at a given time
1 resource / patient at a given time
Schedule beyond visibility parameter
Patients weighted by acuity

Outputs

Expected resources required
Operation start times for near optimal schedule
Expected LOS for each patient

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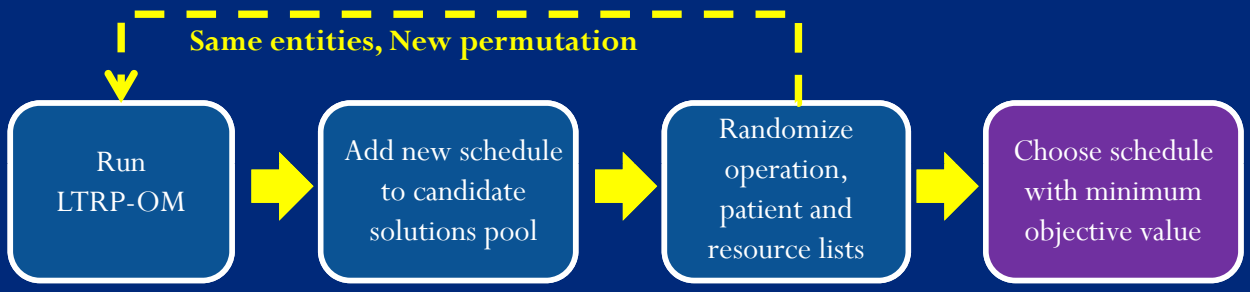
Solver Module Methodology

Listing Algorithm

LTRP-OM : Longest Total Remaining Processing Time on Other Machines

When a resource becomes available, schedule on it the patient with the LTRP-OM

Scheduling Heuristic



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OSCAR : Patient Scheduling

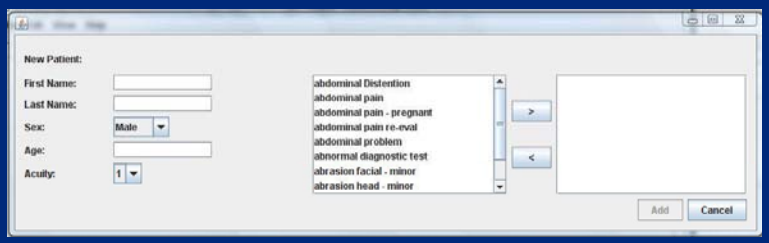
Tasks

Add Patient

Schedule Patient

Add/Remove Test

Reschedule



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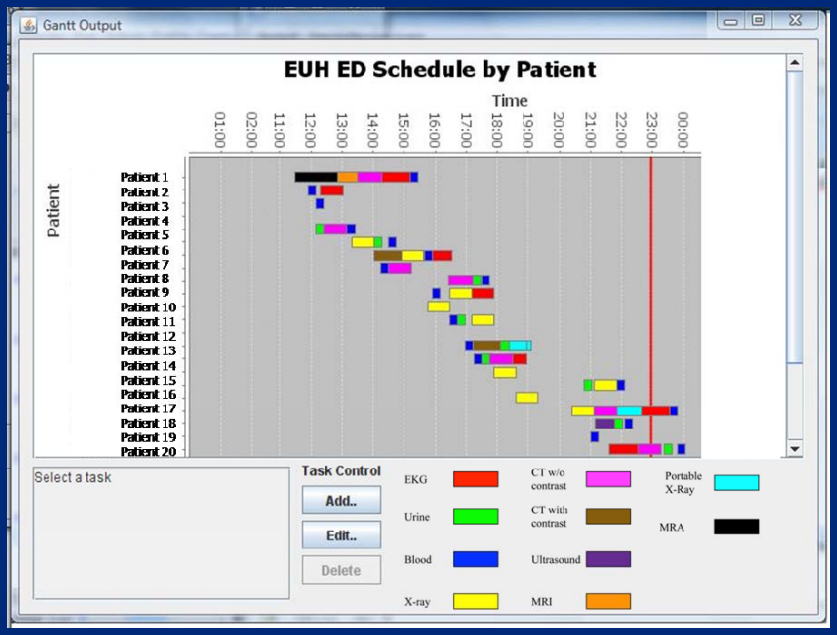

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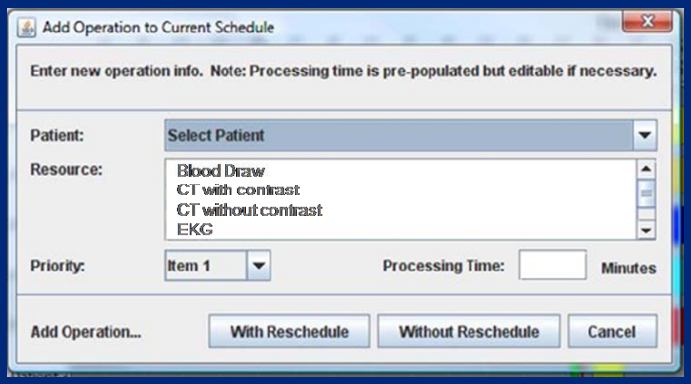

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Validating Schedules

	# Operations	# Patients	Permutations	Runtime	Best Solution	Gap
IP Model	16	3	5,000	1:37:57	541	optimal
OSCAR tool				0:00:27	547	1.1%
IP Model	30	7	10,000	4:22:05	1,336	optimal
OSCAR tool				0:00:01	1,483	9.0%
IP Model*	52	13	20,000	2:29:13	3,266	46.1%
OSCAR tool				0:04:28	3,272	7.3%

* Xpress failed; IP Model value represents the best solution found at the listed runtime.

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Test Cases

Actual versus OSCAR LOS (hours)
January 2010

	Actual		OSCAR		% Difference
Acuity	**μ**	**σ**	**μ**	**σ**	**μ**
1	5.9	3.2	4.0	1.6	-13%
2	7.1	4.6	4.2	1.5	-23%
3	6.1	4.1	4.0	1.8	-18%
4	3.5	2.2	3.0	1.4	-1%
5	1.3	0.1	1.2	0.1	-5%
Overall	**6.1**	**4.2**	**3.9**	**1.7**	**-17%**

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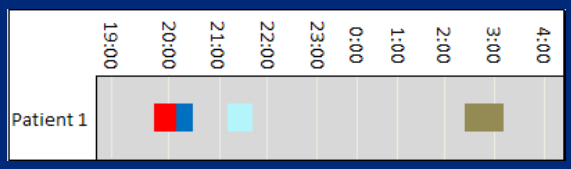
Sample Patient Schedules

Actual



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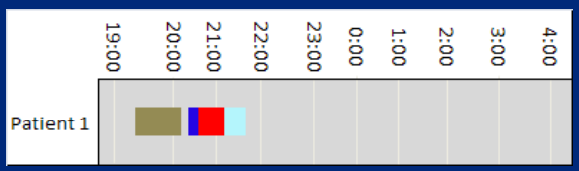
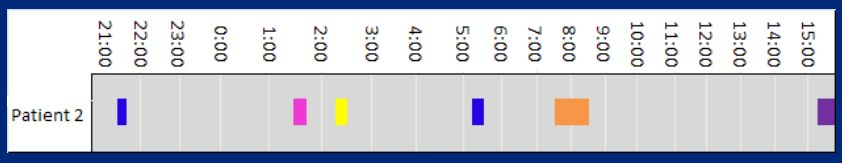


Actual



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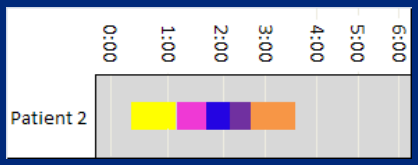

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OSCAR: User views

User

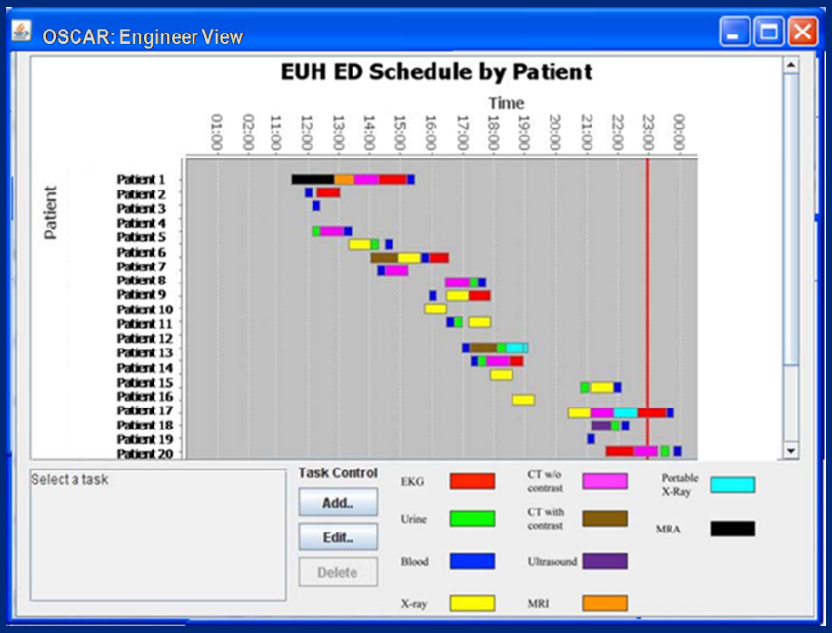
Engineer

Resource

Doctor

Nurse

Patient



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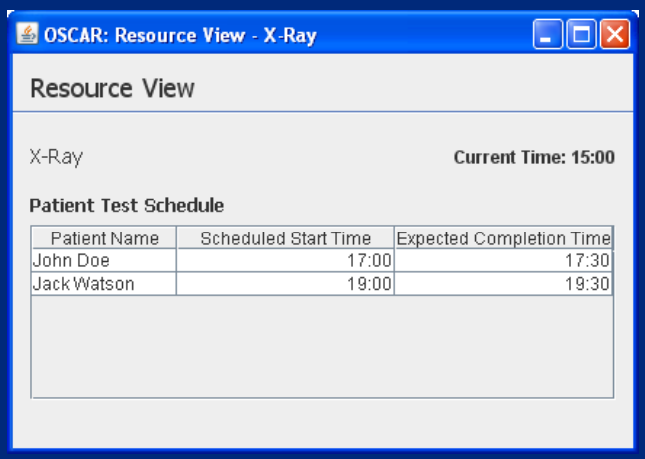

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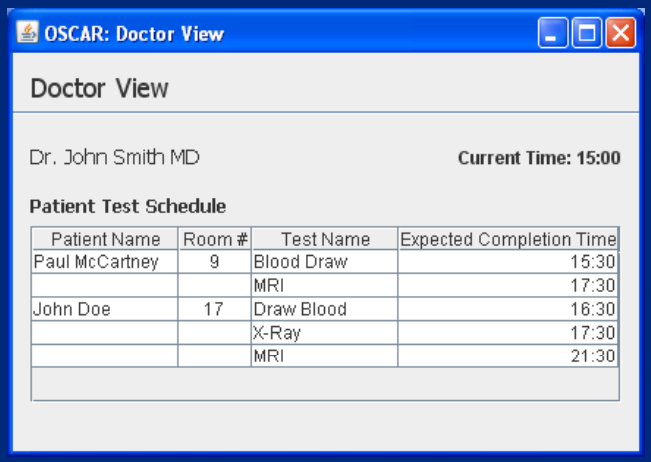

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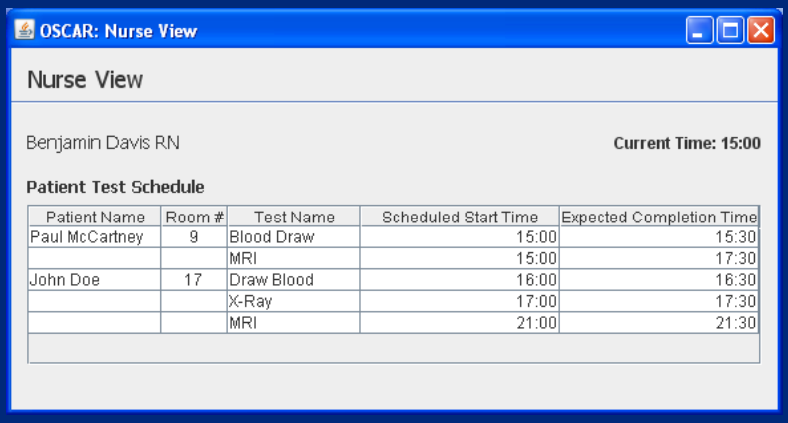

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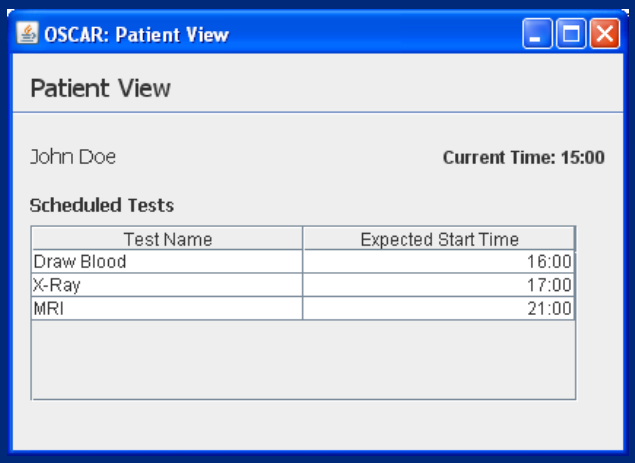

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NEDOCs Score Parameters

- Total number of patients in ED
- Total number of beds in ED
- Total number of hospital beds at hospital
- Total number of Acuity Level 1 patients, ICU bed requests
- Total number of patients waiting in ED for hospital admission
- Longest waiting time in ED Waiting Room
- Longest waiting time for hospital admission for ED patients

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Value

Parameter	ED	OSCAR
NEDOCs Score μ	152.5709	146.4024
NEDOCs Score σ	10.7159	12.85131
% Reduction NEDOCs Score	4%	
Jan Times on Diversion	24	16
% Diversion Reduction	33%	
Increase EMS Patients	8	

Additional Monthly Revenue	$5,048
Additional Yearly Revenue	$60,576

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Next Steps

- Tool submitted for a Technical Review
  - Integration into Cerner system
  - Estimated cost from EUH Information Services
- Grant proposal for continued development and implementation

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Questions

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