

# Simulation of Kanban-based scheduling for Systems of Systems

**By**

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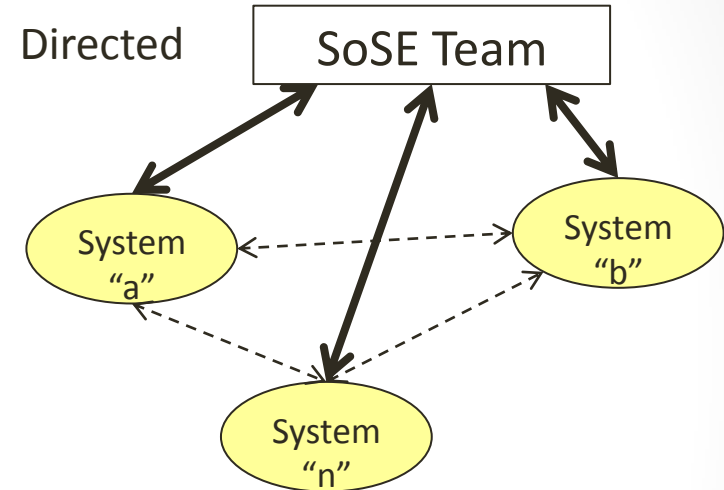
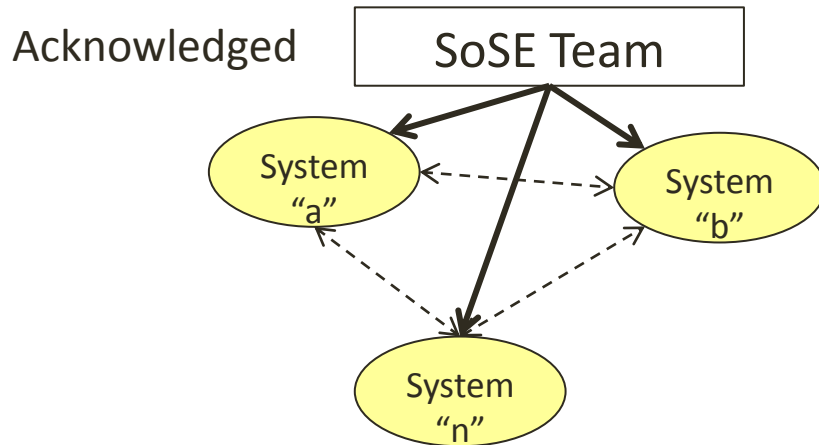
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# Outline

- Part I. Kanban-based scheduling in SoS
  - SoS environments
  - KSS principles
- Part II. Simulation model
  - Organizational model
  - Governance model
  - Work items networks model
  - Inputs and outputs
- Part III. Experiments and simulation results

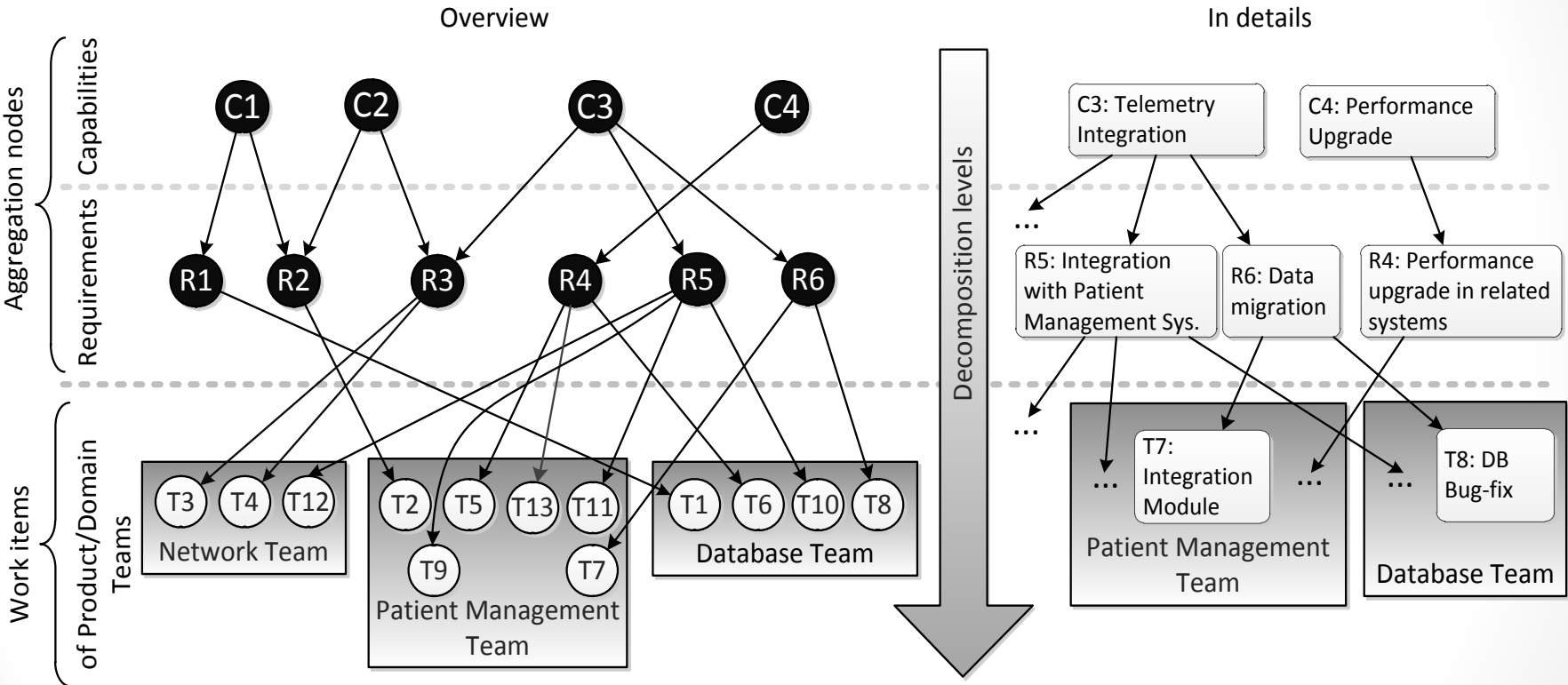
# System of Systems

- Acknowledged and directed SoS:

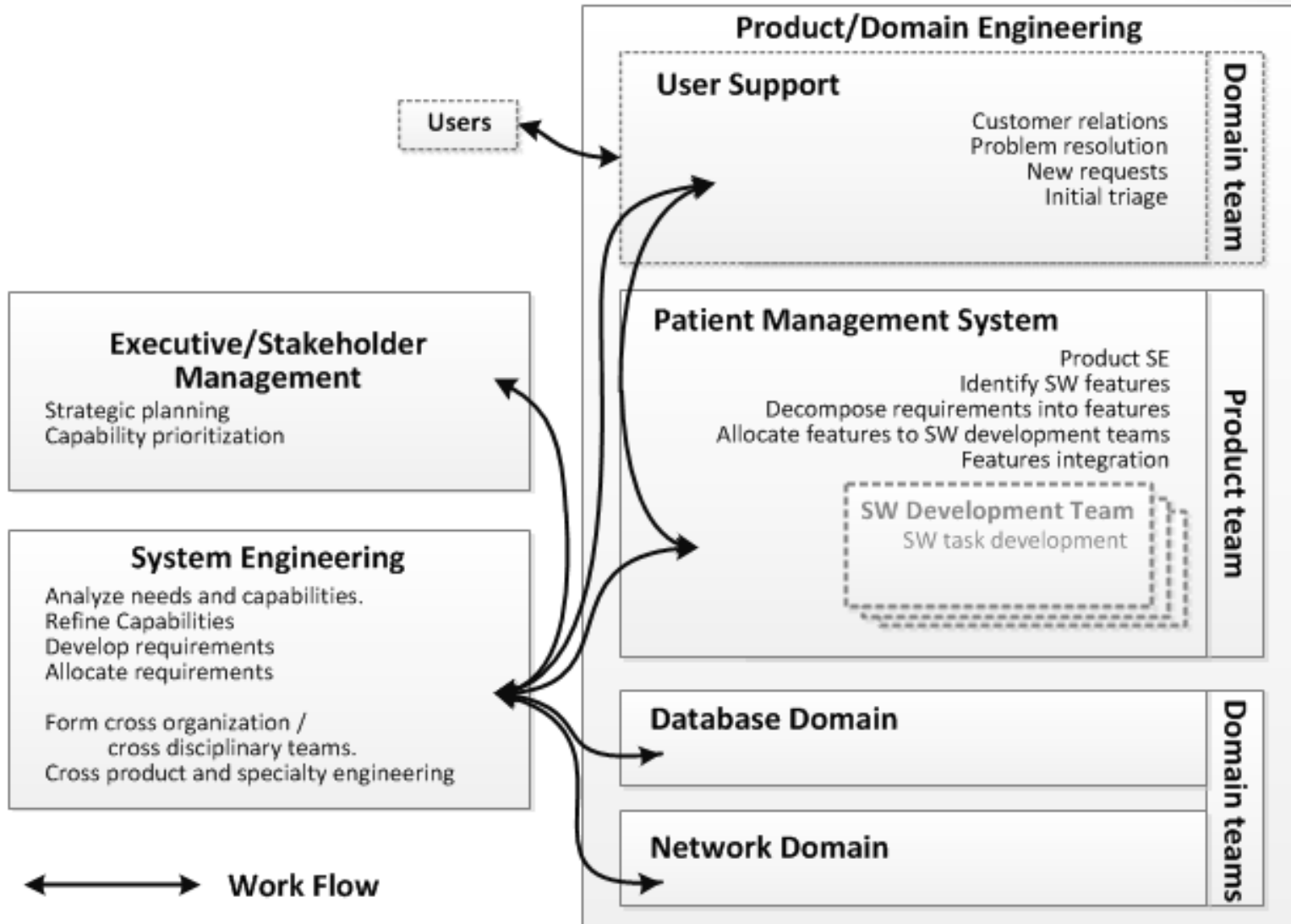


- Three main organizational levels:
  - Executive/Stakeholder management
  - System Engineering team
  - Product/Domain teams

# Capabilities to products flow



# Health care SoS example



# System of Systems' observed issues

- Ineffective communication between different organizational levels
- Lack of visibility (status of SoS capabilities)
- Inefficient use of engineering resources
- Time wasted on context switching (multitasking overhead)
- Valuable capabilities are not delivered first or incomplete capabilities delivered:
  - value delivery cadence is not satisfactory
  - stakeholders cannot effectively update priorities when values change

# Key measures for Kanban research

- Value delivered over time
- Schedule and effort
- Efficiency measures:
  - Number of suspended/interrupted tasks
  - Number of disruptive tasks
  - E-factor =  $\text{Uninterrupted hours} / \text{Hours present}$

# Kanban-based scheduling process

- Eliminate waste
  - Minimize context switching
  - Limit work in progress
- Make process more visible, transparent, and quantifiable
  - Kanban boards
  - WIP status and obstacles
  - Value-based scheduling with respect to SoS capabilities
- Efficient/explicit value control
  - Value-based work prioritization
  - Stakeholders explicitly define value of SoS' capabilities
  - Value assigned and distributed explicitly



## Executive/Stakeholder Management

Strategic planning  
Capability prioritization

### Kanban board

**TO DO:**

▲ C3: Telemetry  
Integration  
▲ C4: Perfms.  
upgrades

**WIP:**

▲ C1: Database  
monitoring S/W  
▲ C2: Network  
diagnosing S/W

**DONE:**

▲ C0: Diagnostics  
S/W

## System Engineering

Analyze needs and capabilities.  
Refine Capabilities  
Develop requirements  
Allocate requirements

Form cross organization /  
cross disciplinary teams.  
Cross product and specialty engineering

### Kanban board

**TO DO:**

▲ R4: ...  
▲ R5: ...

**WIP:**

▲ R2: ...  
▲ R3: ...  
▲ R6: ...

**DONE:**

▲ R1: ...

## Product/Domain Engineering

### User Support

Users

Customer relations  
Initial triage

Domain team

### Kanban board

**TO DO:**

▲ B6: Wrong  
data in DB  
▲ B7: IU bug  
in...

**WIP:**

▲ B4: Wrong date  
reported  
▲ B3: ...  
▲ B2: ...

**DONE:**

▲ B1: Wrong  
midnight time  
format

### Patient Management System

Product SE  
Identify SW features  
Decompose requirements into features  
Allocate features to SW development teams  
Features integration

Product team

### Kanban board

**TO DO:**

▲ T4: ...  
▲ T5: ...

**WIP:**

▲ T2: ...  
▲ T3: ...  
▲ T6: ...

**DONE:**

▲ T1: ...

### SW Development Team

SW task development

### Kanban board

**TO DO:**

▲ T6: ...  
▲ T7: ...

**WIP:**

▲ T5: ...  
▲ T4: ...

**DONE:**

▲ T1: ...  
▲ T2: ...

### Database Domain

### Kanban board

**TO DO:**

▲ T4: ...  
▲ T5: ...

**WIP:**

▲ T2: ...  
▲ T3: ...  
▲ T6: ...

**DONE:**

▲ T1: ...

Domain teams

### Network Domain

### Kanban board

**TO DO:**

▲ T4: ...  
▲ T5: ...

**WIP:**

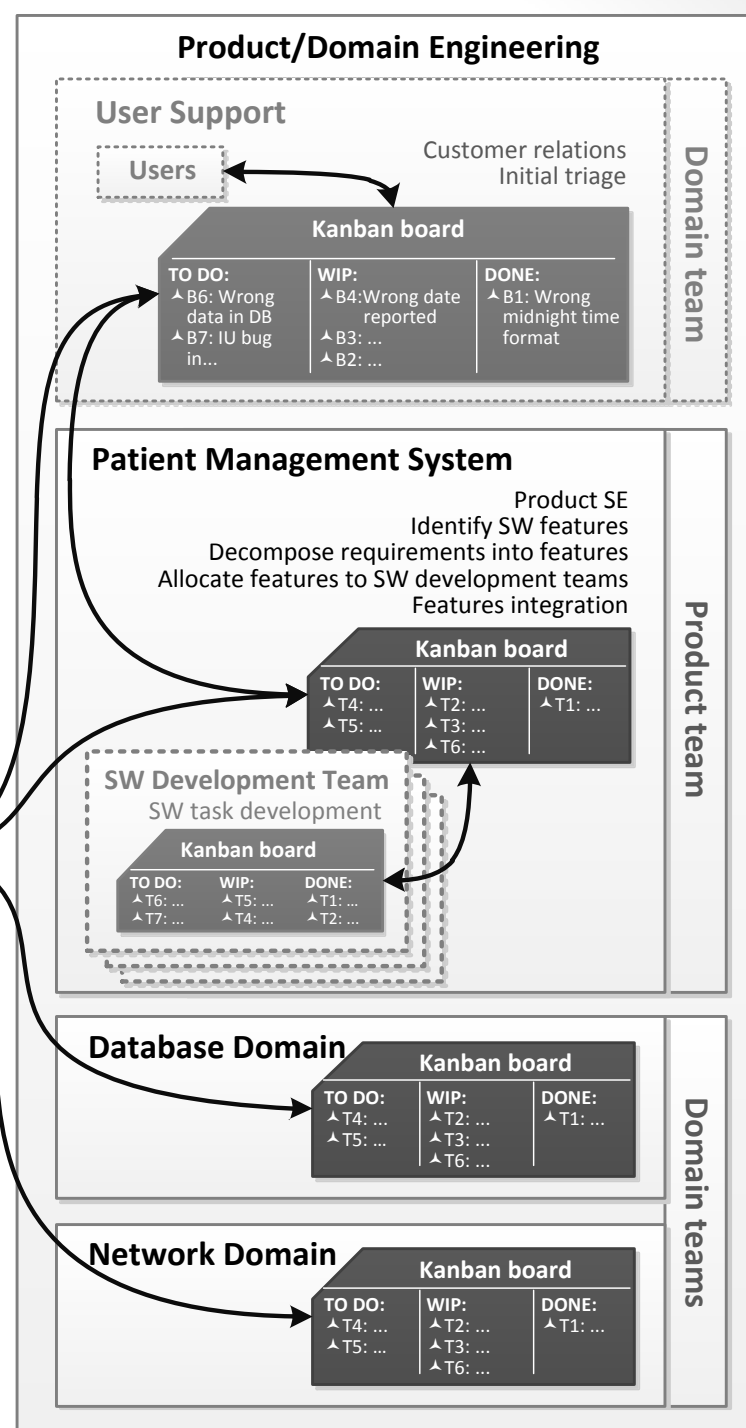
▲ T2: ...  
▲ T3: ...  
▲ T6: ...

**DONE:**

▲ T1: ...



Work Flow



# Simulation model

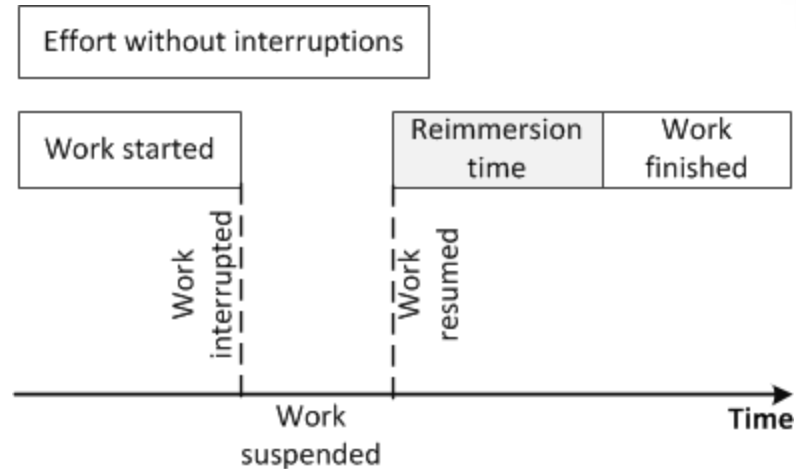
- Agent based model
- Three aspects of the model:
  - Organizational model – structure of product and domain teams, SE team, stakeholders, etc.
  - Governance model – defines agents' behavior:
    - scheduling algorithms
    - queues management
    - resource multitasking
    - WIs and resource outsourcing policies
  - WI network model – all WI and their relationships, defines:
    - Work decomposition
    - Value flow

# Inputs and outputs

- Inputs:
  - Organizational structure
  - Governance model configuration
  - Event scenario – events that describe how WIs originate and evolve in the simulation model.
- Outputs:
  - Value delivered over time
  - Number of work items in progress
  - Number of fully complete & delivered capabilities over time
  - Inefficiently used effort (waste of effort):
    - Effort spent on context switching between tasks / multitasking

# Modeling context switching

- Reimmersion time:



- Modeling the reimmersion time
  - Constant time: 1 hour/ 1 timeframe
  - Variable reimmersion time based on
    - Task complexity
    - Assignment to another resource
    - Length of suspension

## Part III

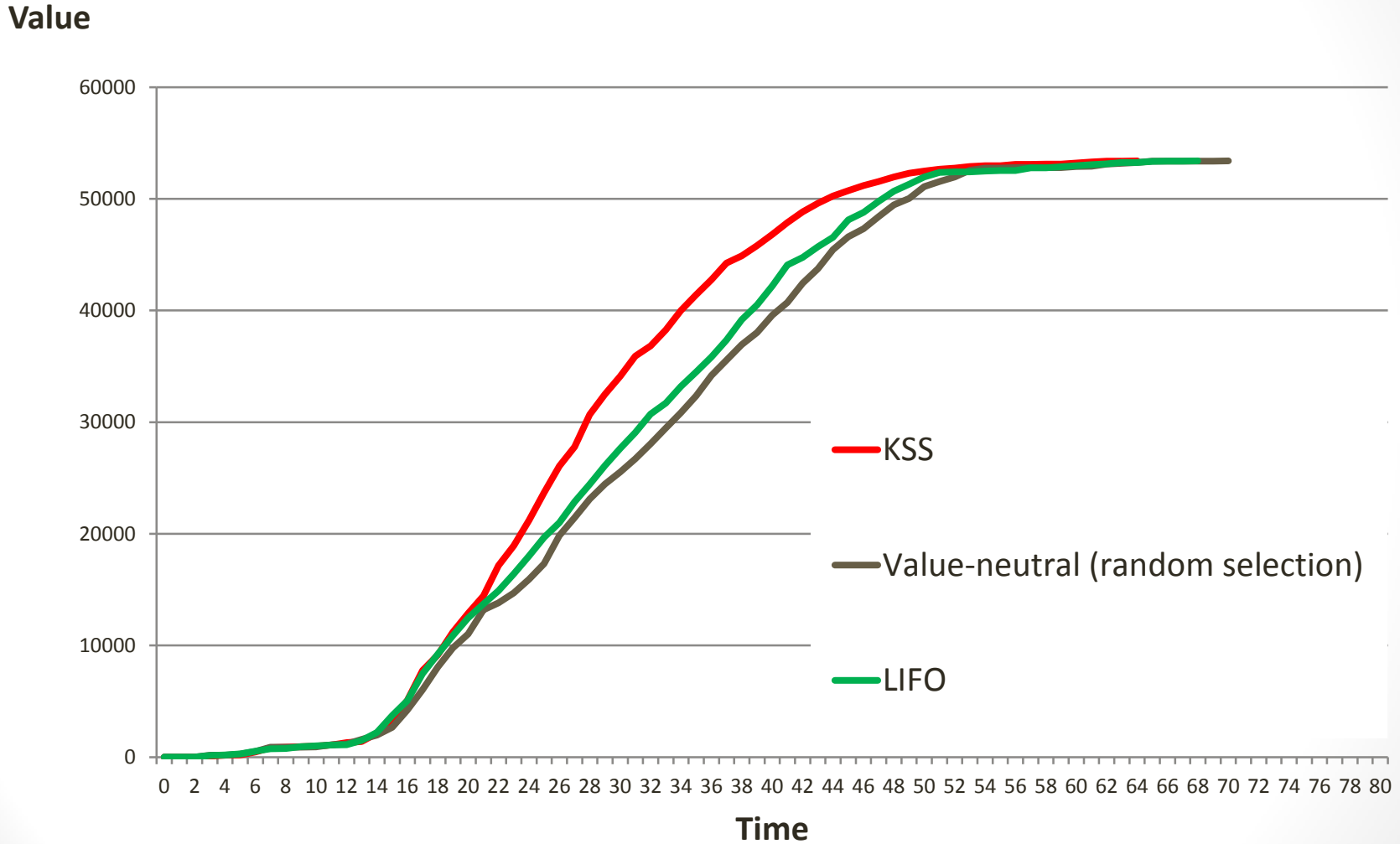
# Experiments and results

- Experiment 1
  - Scheduling algorithms: KSS, LIFO, value-neutral
  - Compares
    - value delivered over time
    - total schedule and effort
    - Suspended/interrupted work
- Experiment 2
  - Scheduling algorithms: KSS, LIFO, FIFO, value-neutral
  - Compares
    - value delivered over time
    - Capability completeness
- Experiment 3
  - KSS scheduling
  - Shows impact of multitasking and work interruptions

# Experiment 1

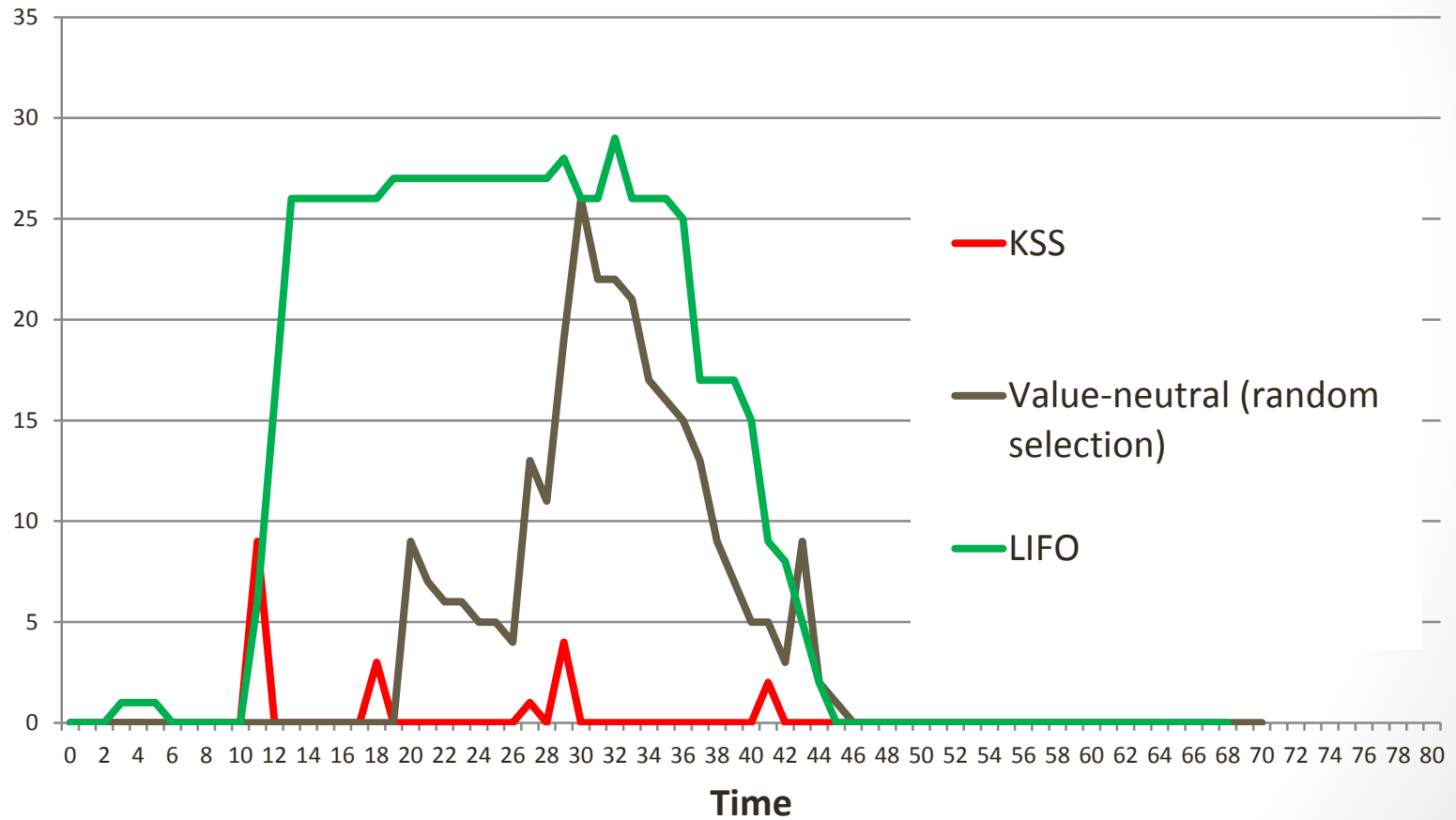
- 10 constituent teams (20 members each)
  - + SoS system engineering team
- 20 new capabilities at start
- Each capability unfolds into 30 requirements on average
- Each requirement unfolds into 9 tasks on average
- Each tasks takes 3-15 days

# Results: experiment 1



# Results: experiment 1

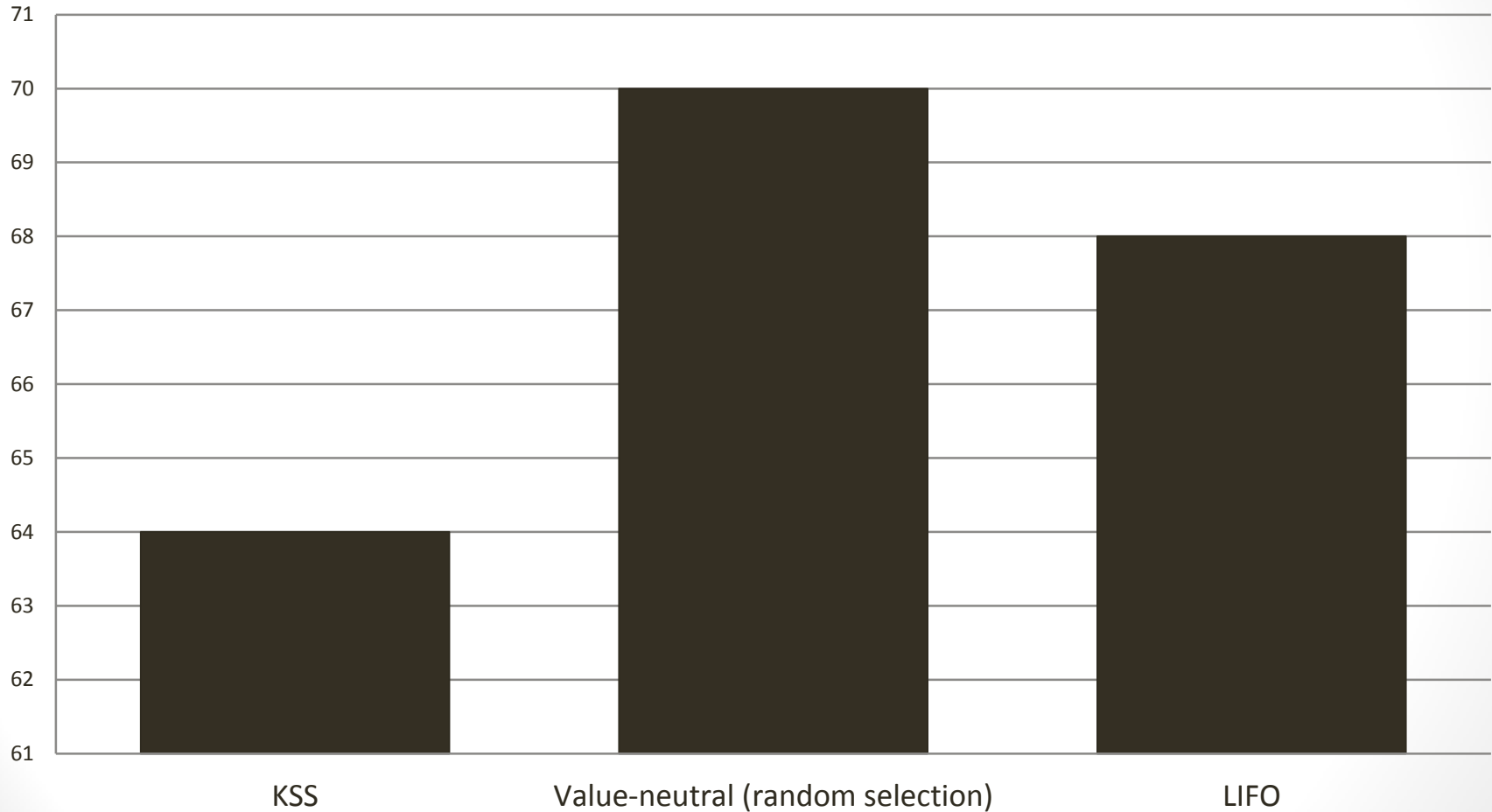
Number of  
Suspended Tasks





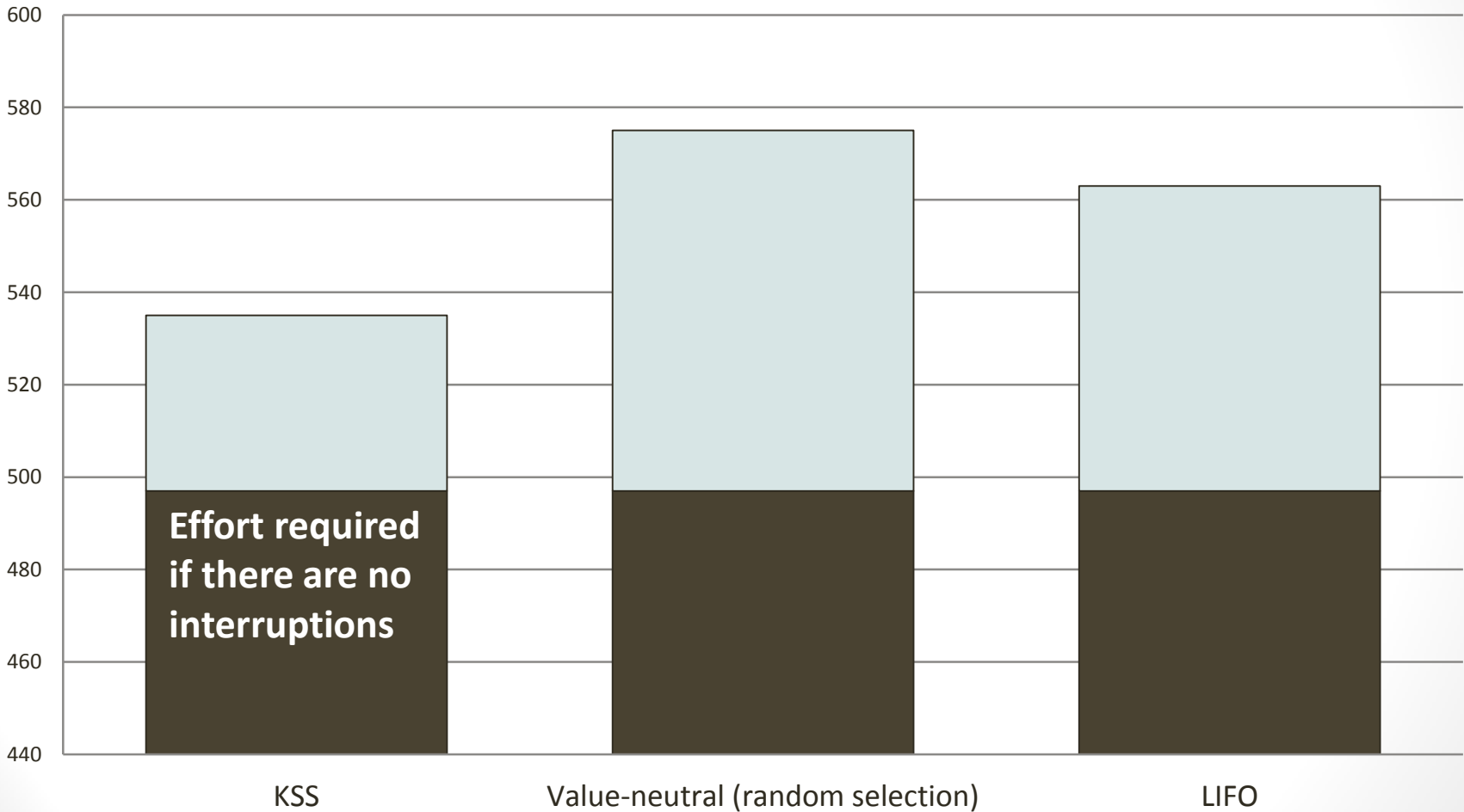
# Results: experiment 1

Total schedule (calendar days)



# Results: experiment 1

Total effort (person-days)

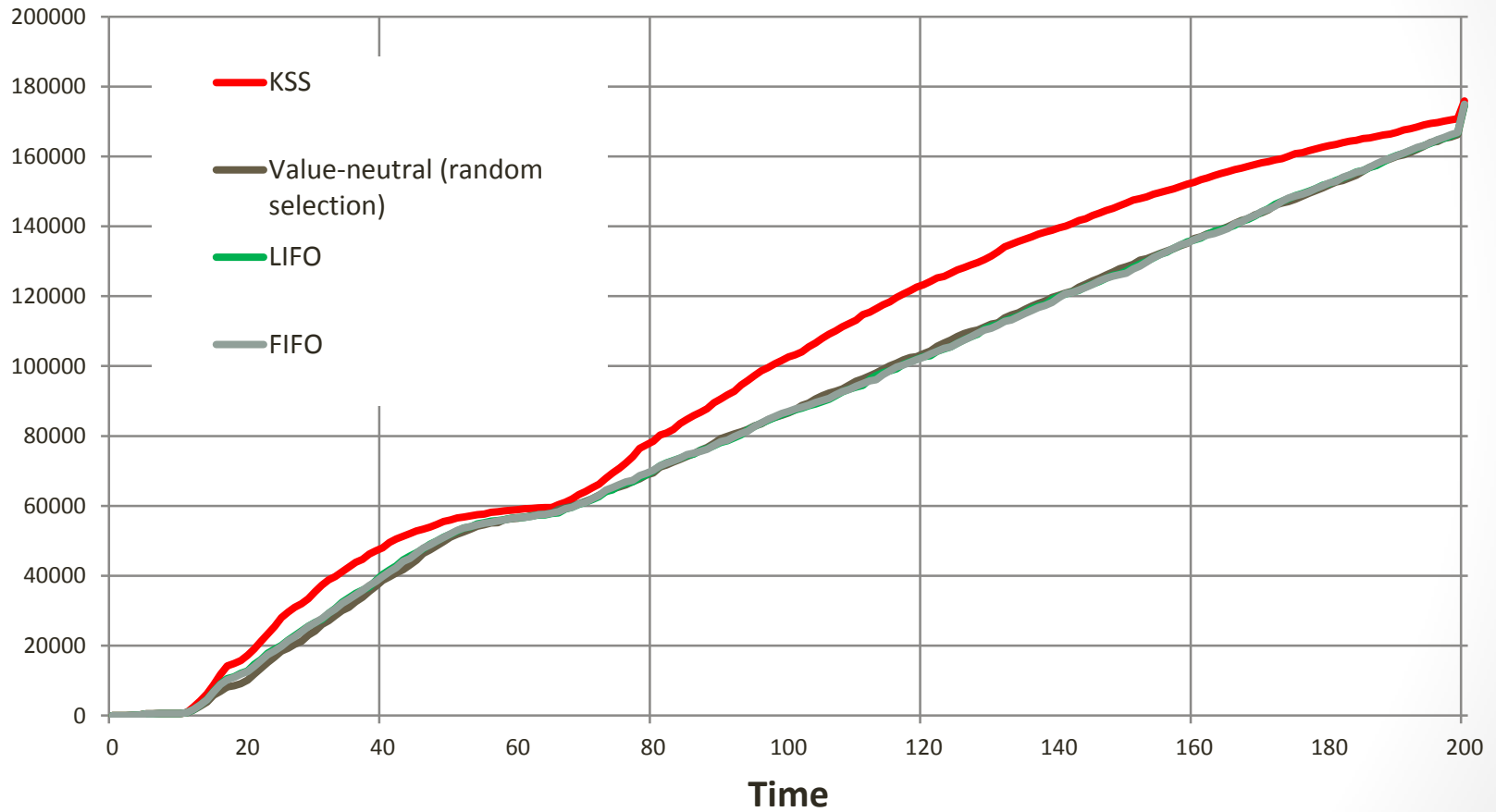


# Results: experiment 2

- 15 teams (12 members each) + system engineering team.
- 10 new capabilities at start
- 20 more capabilities added during the simulation
- Each capability unfolds into 30 requirements on average
- Each requirement unfolds into 10 tasks on average.
- Each tasks takes 3-15 days.
- There are 10 expedite tasks that cause blocked work (blocked tasks)
- Simulation time-frame: 1 hour
- Simulation length (fixed time simulation): 200 days/1600 hours.

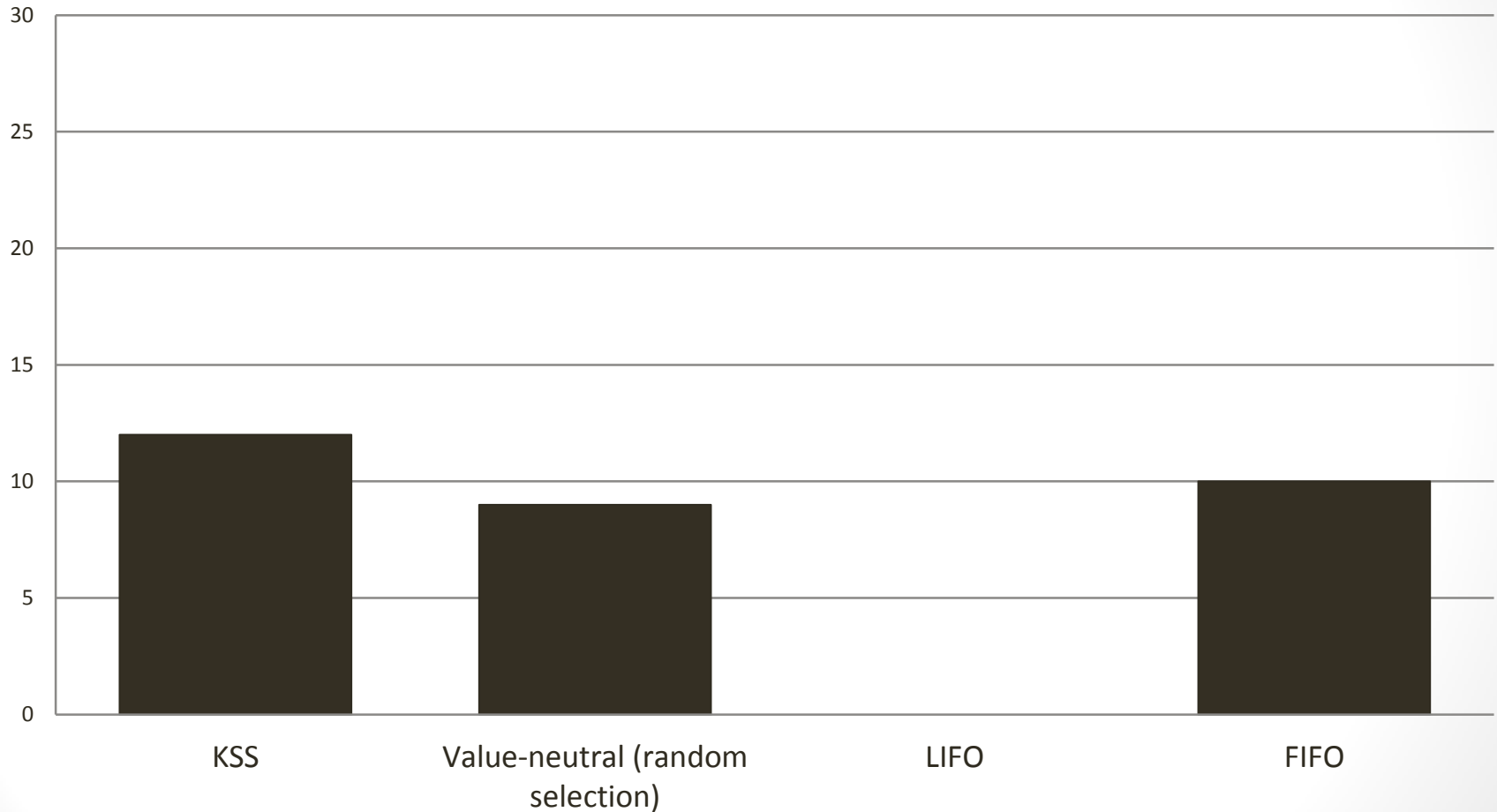
# Results: experiment 2

Value



# Results: experiment 2

**Number of 100% complete capabilities**

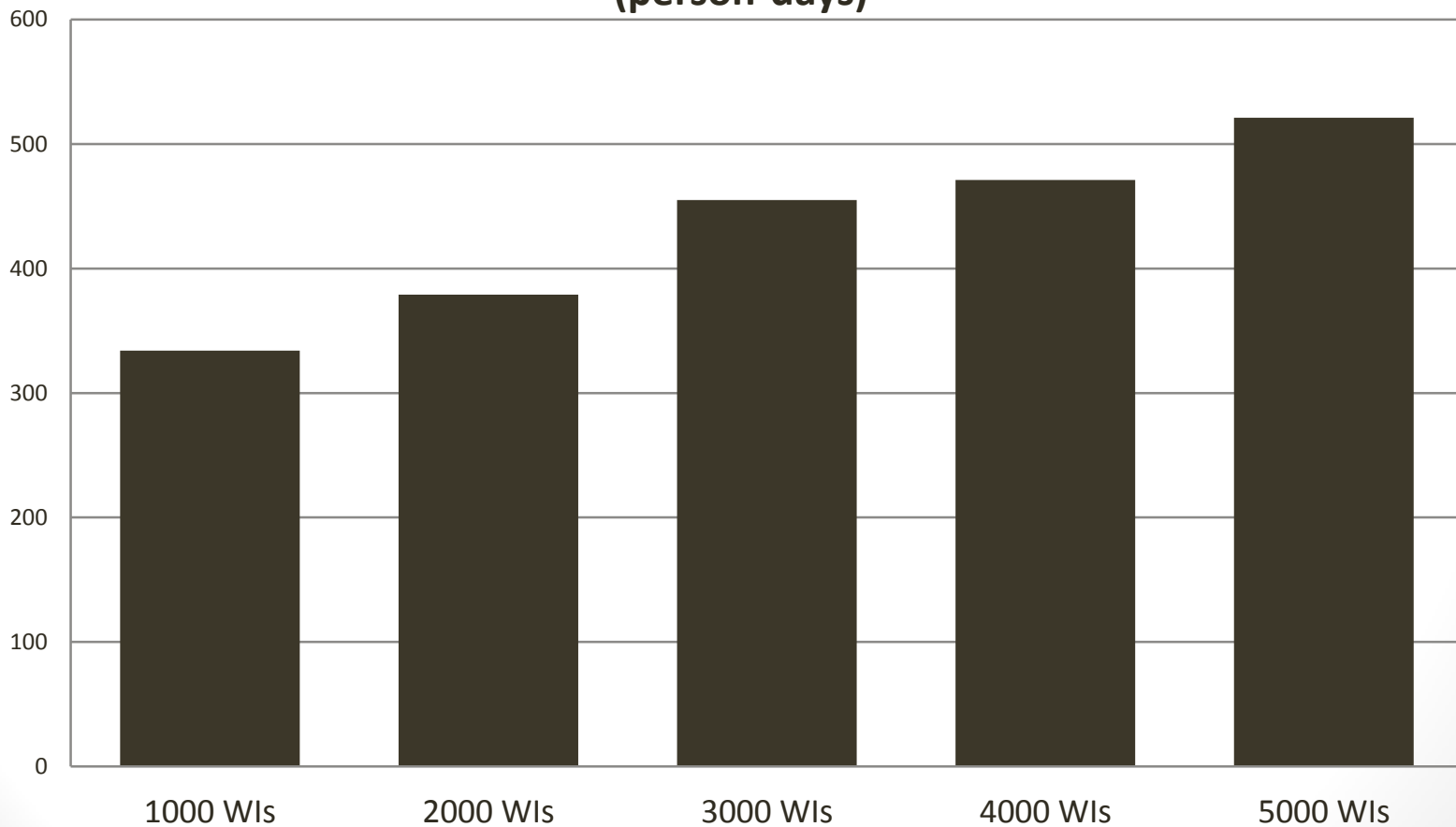


# Results: experiment 3

- We generated five groups of experiments with 100 experiments in each group. Each groups had a different number of WIs but the same organizational structure (5+1 teams). Each team had 15 resources.
- In the first group, we had 1000 WIs, in the second we had 2000 WIs, and so on.
- Nominal effort required for each WI was in interval 1-5 person-days.
- 100 disruptive WIs were introduced in the simulation.

# Impact of interruptions in scale experiment 3

**Effort spent on context switching  
(person-days)**



# Conclusion and future work

## Impact of Kanban process with respect to key measures

Measure	
Value	More value delivered over time
Effort and schedule	<ul style="list-style-type: none"><li>• Save effort on unnecessary multitasking (in simulation it reduces effort spent on context switching by 40%)</li><li>• Improve capability delivery cadence</li></ul>
Efficiency	<ul style="list-style-type: none"><li>• Reduce unnecessary interruptions and multitasking</li><li>• Focus on completing capabilities (avoiding situations when everything is 90% complete and nothing delivered)</li><li>• Reduce number of suspended/interrupted tasks (in simulation it reduces number of suspended tasks by 2-3 times)</li><li>• Reduces the E-factor</li></ul>



# Future work

Next steps:

- Pilot the Kanban scheduling with several organizations
- Fine-tune the simulation using empirical data and organizations' feedback

For additional information and piloting the KSS contact:

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# Q&A

- Questions?

# References

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