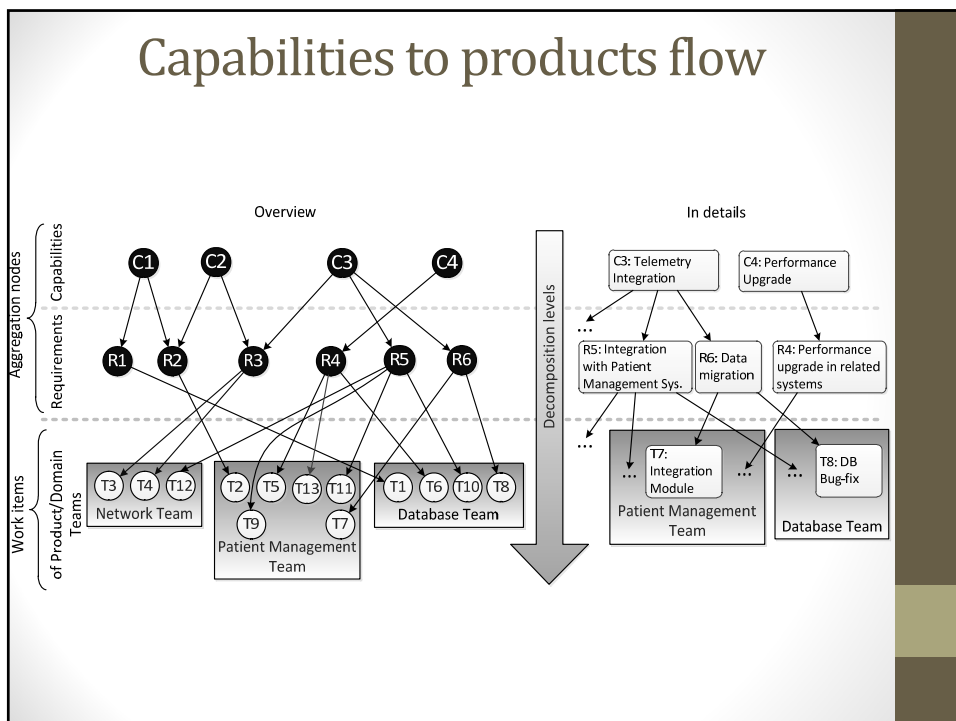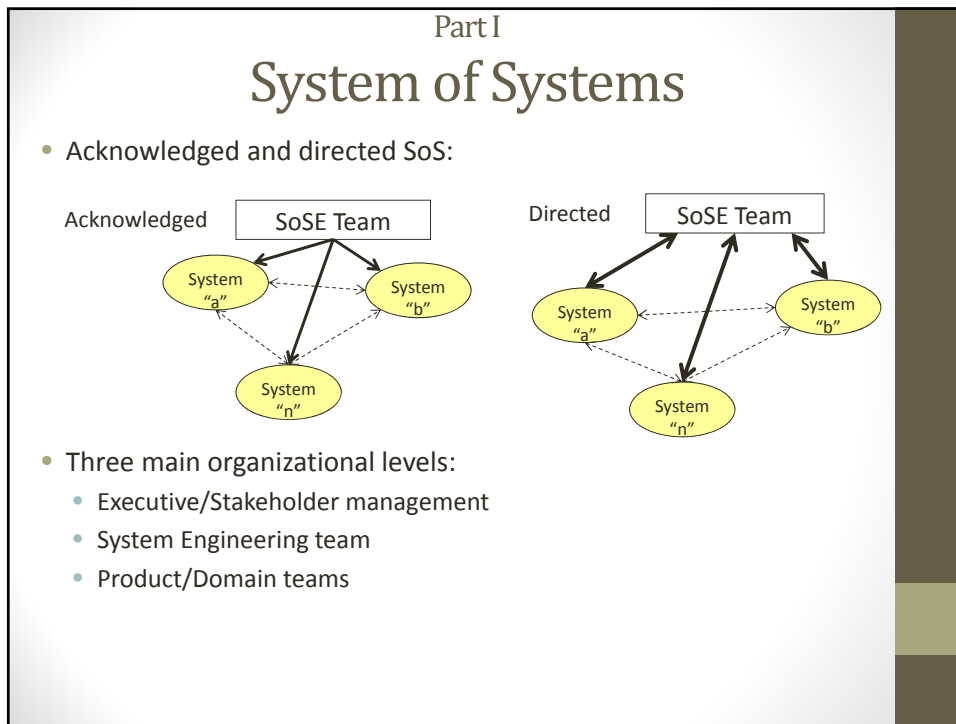# Simulation of Kanban-based scheduling for Systems of Systems
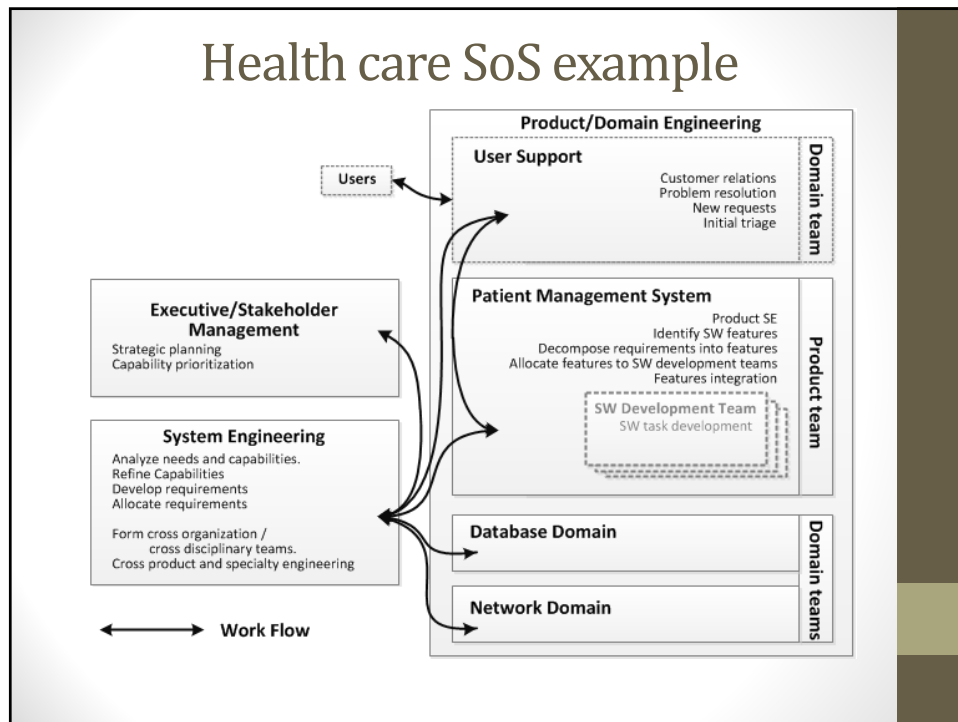
By
Alexey Tregubov, Jo Ann Lane

University of Southern California
Los Angeles, CA

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

Part I
System of Systems

- Acknowledged and directed SoS:

Acknowledged

Directed

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

Capabilities to products flow

Health care SoS example
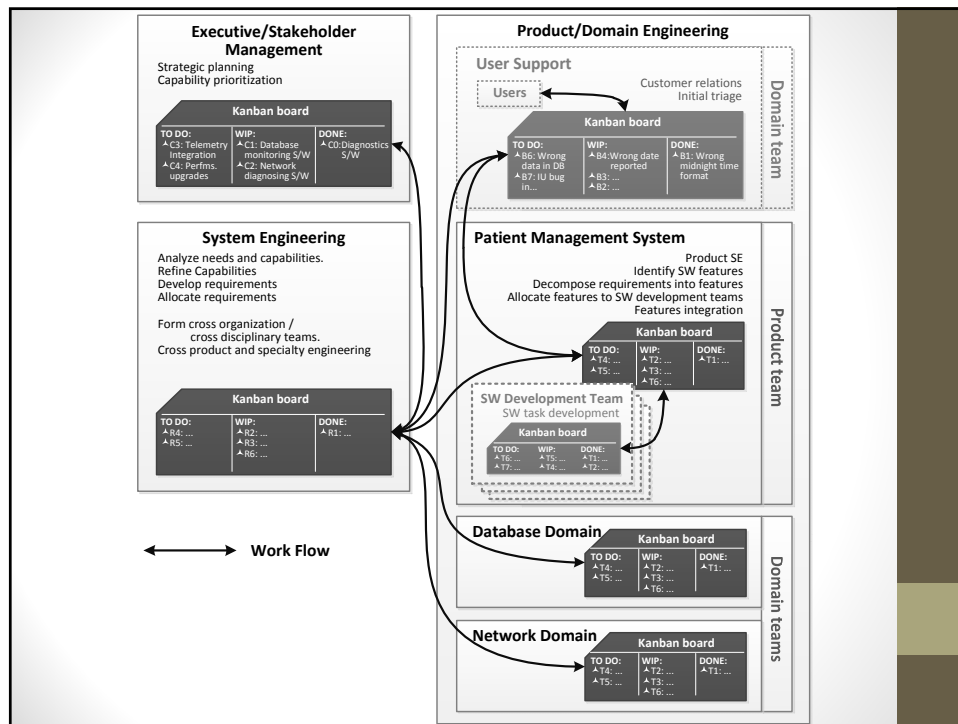

System of Systems'
observed issues

- 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 indicators/metrics:
  - Number of suspended/interrupted tasks
  - Number of disruptive tasks
  - E-factor = Uninterrupted hours / 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:	WIP:	DONE:
C3: Telemetry Integration	C1: Database monitoring S/W	C0:Diagnostics S/W
C4: Perfms. upgrades	C2: Network diagnosing S/W	

Product/Domain Engineering

User Support

Users

Customer relations
Initial triage

Kanban board

TO DO:	WIP:	DONE:
B6: Wrong data in DB	B4:Wrong date reported	B1: Wrong midnight time format
B7: IU bug in...	B3: ...	
	B2: ...	

Domain team

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:	WIP:	DONE:
R4: ...	R2: ...	R1: ...
R5: ...	R3: ...	
	R6: ...	

Patient Management System

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

Kanban board

TO DO:	WIP:	DONE:
T4: ...	T2: ...	T1: ...
T5: ...	T3: ...	
	T6: ...	

SW Development Team
SW task development

Kanban board

TO DO:	WIP:	DONE:
T6: ...	T5: ...	T1: ...
T7: ...	T4: ...	T2: ...

Product team

Database Domain

Kanban board

TO DO:	WIP:	DONE:
T4: ...	T2: ...	T1: ...
T5: ...	T3: ...	
	T6: ...	

Network Domain

Kanban board

TO DO:	WIP:	DONE:
T4: ...	T2: ...	T1: ...
T5: ...	T3: ...	
	T6: ...	

Domain teams

←——→ Work Flow

---

Part II
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):
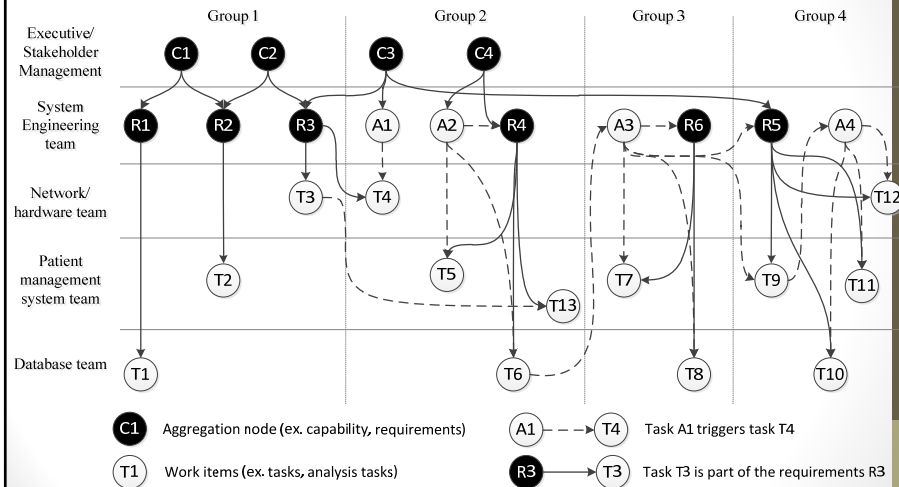   - Effort spent on context switching between tasks / multitasking

Modeling context switching

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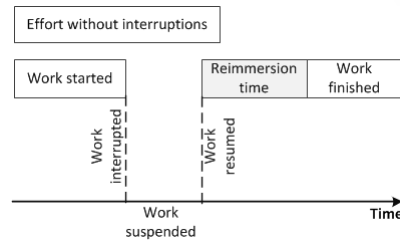
- Modeling the reimmersion time
  - Constant time: 1 hour/ 1 timeframe
  - Coming soon: variable reimmersion time based on
    - Task complexity
    - Assignment to another resource
    - Length of suspension

2/24/2016

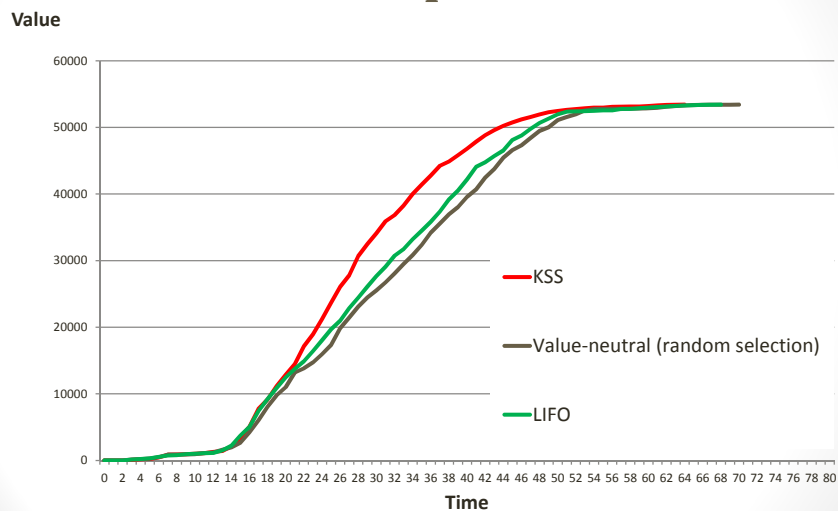## Work Items Network (example)

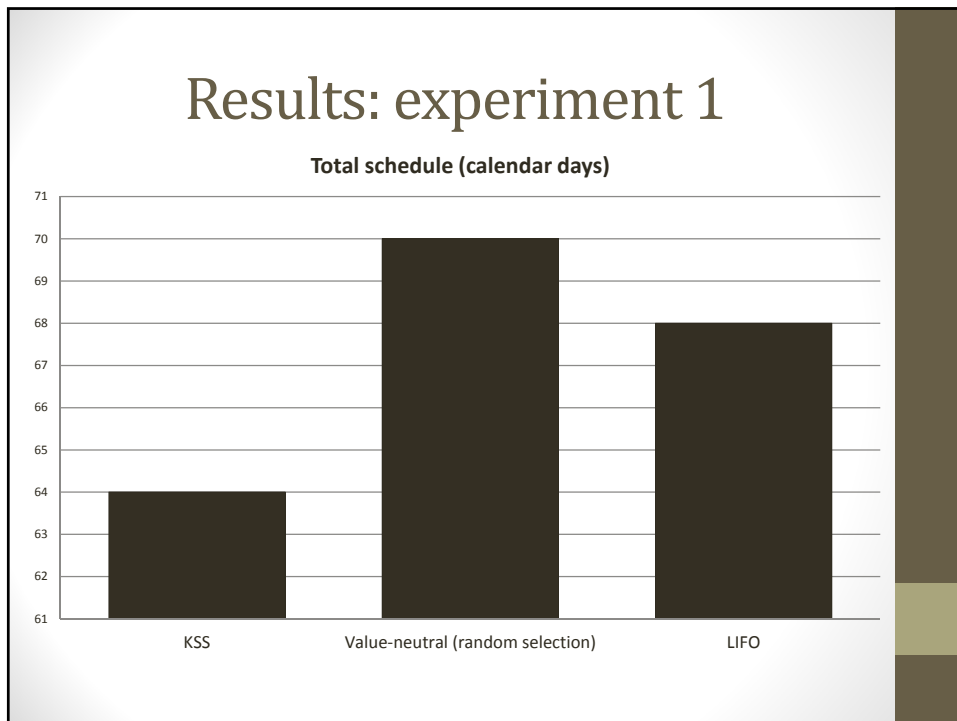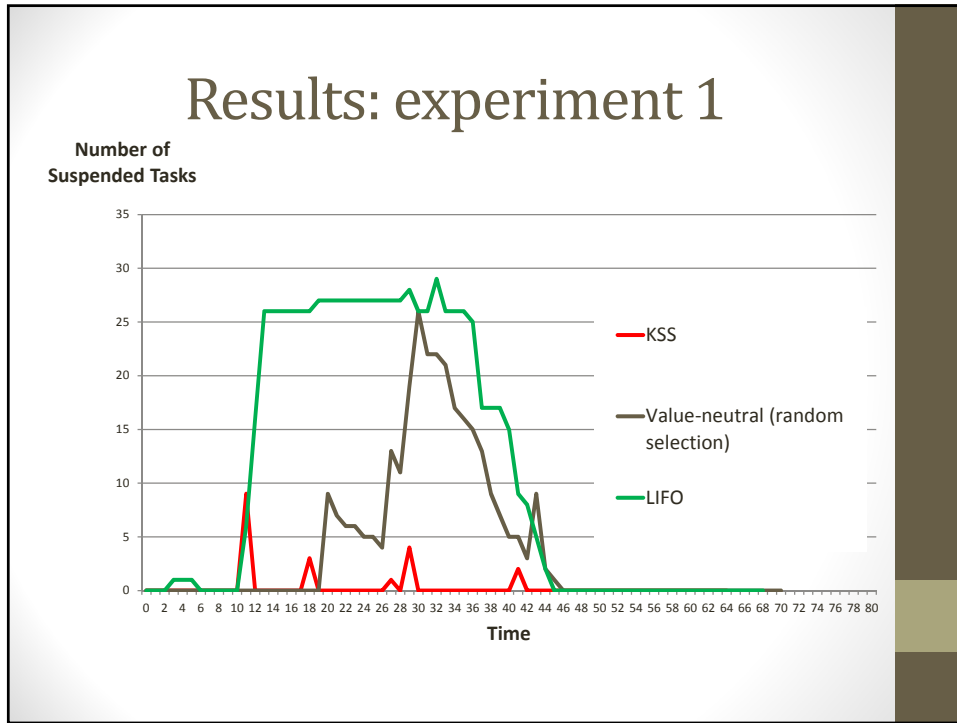Part III

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
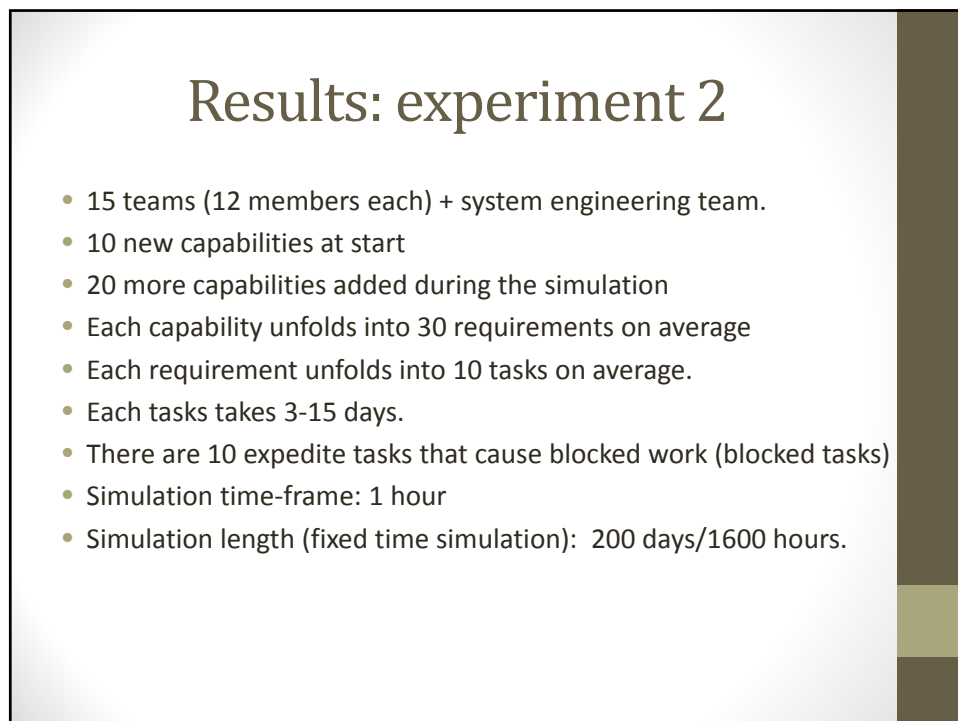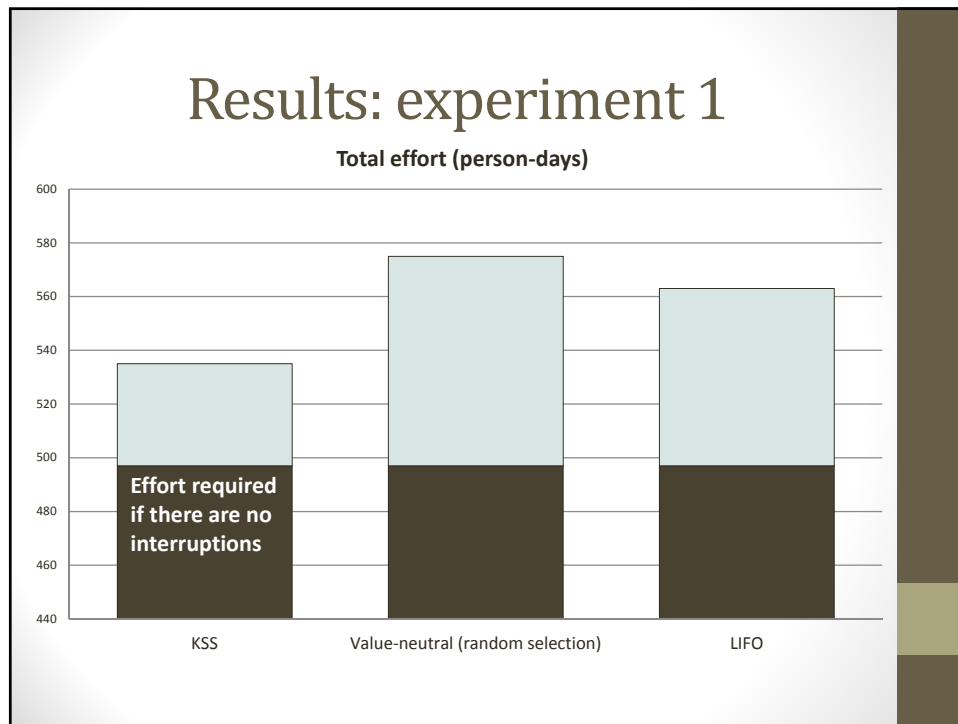 - Shows impact of multitasking and work interruptions
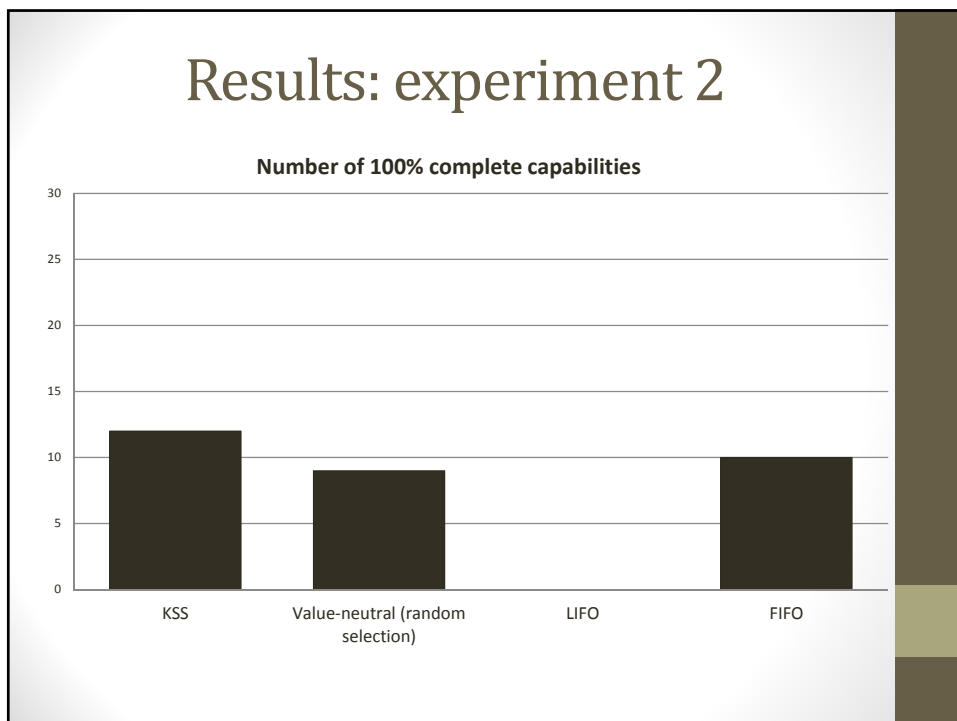
Experiment 1

- 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

Legend:
- KSS
- Value-neutral (random selection)
- LIFO

Time

Results: experiment 1

Total schedule (calendar days)

KSS — Value-neutral (random selection) — LIFO

Results: experiment 1

Total effort (person-days)

Effort required if there are no interruptions

KSS	Value-neutral (random selection)	LIFO

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
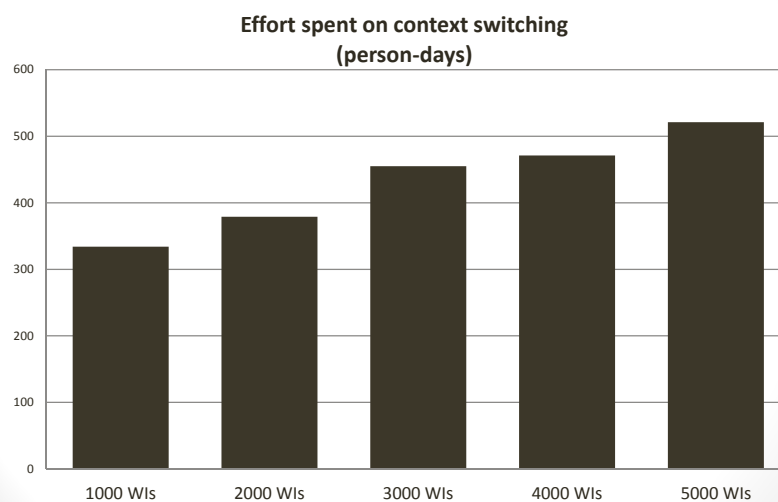
Number of 100% complete capabilities

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)

600	
500	
400	
300	
200	
100	
0	
	1000 WIs 2000 WIs 3000 WIs 4000 WIs 5000 WIs

Conclusion and future work

Impact of Kanban process with respect to key measures

Measure	
Value	More value delivered over time
Effort and schedule	• Save effort on unnecessary multitasking (in simulation it reduces effort spent on context switching by 40%) • Improve capability delivery cadence
Efficiency	• Reduce unnecessary interruptions and multitasking • Focus on completing capabilities (avoiding situations when everything is 90% complete and nothing delivered) • Reduce number of suspended/interrupted tasks (in simulation it reduces number of suspended tasks by 2-3 times) • Reduces the E-factor

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:
• Alexey Tregubov tregubov@usc.edu

Q&A

- Questions?

References

- Tregubov, A. and Lane, J.A., 2015. Simulation of Kanban-based Scheduling for Systems of Systems: Initial Results. Procedia Computer Science, 44, pp.224-233.
- DeMarco, T. and Lister, T., 2013. Peopleware: productive projects and teams. Addison-Wesley.
- Boehm, B. and Turner, R., 2003. Balancing Agility and Discipline: A Guide for the Perplexed, Portable Documents. Addison-Wesley Professional.
- Dzubak, C.M., 2008. Multitasking: The good, the bad, and the unknown. The Journal of the Association for the Tutoring Profession, 1(2), pp.1-12.
- Jett, Q.R. and George, J.M., 2003. Work interrupted: A closer look at the role of interruptions in organizational life. Academy of Management Review, 28(3), pp.494-507.

Contacts

- Alexey Tregubov:
  - tregubov@usc.edu
  - http://atregubov.com