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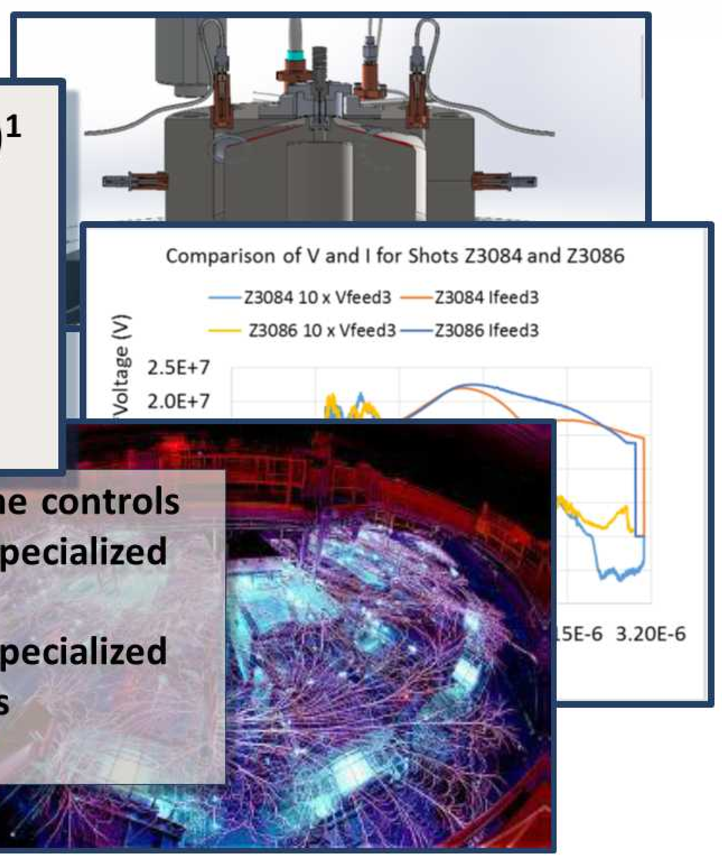
A Simple Temporal Network for Coordination of a Collaborative System-of-Systems

M. A. Schaffner
R&D Systems Engineer
Z Machine Shot Director

Context



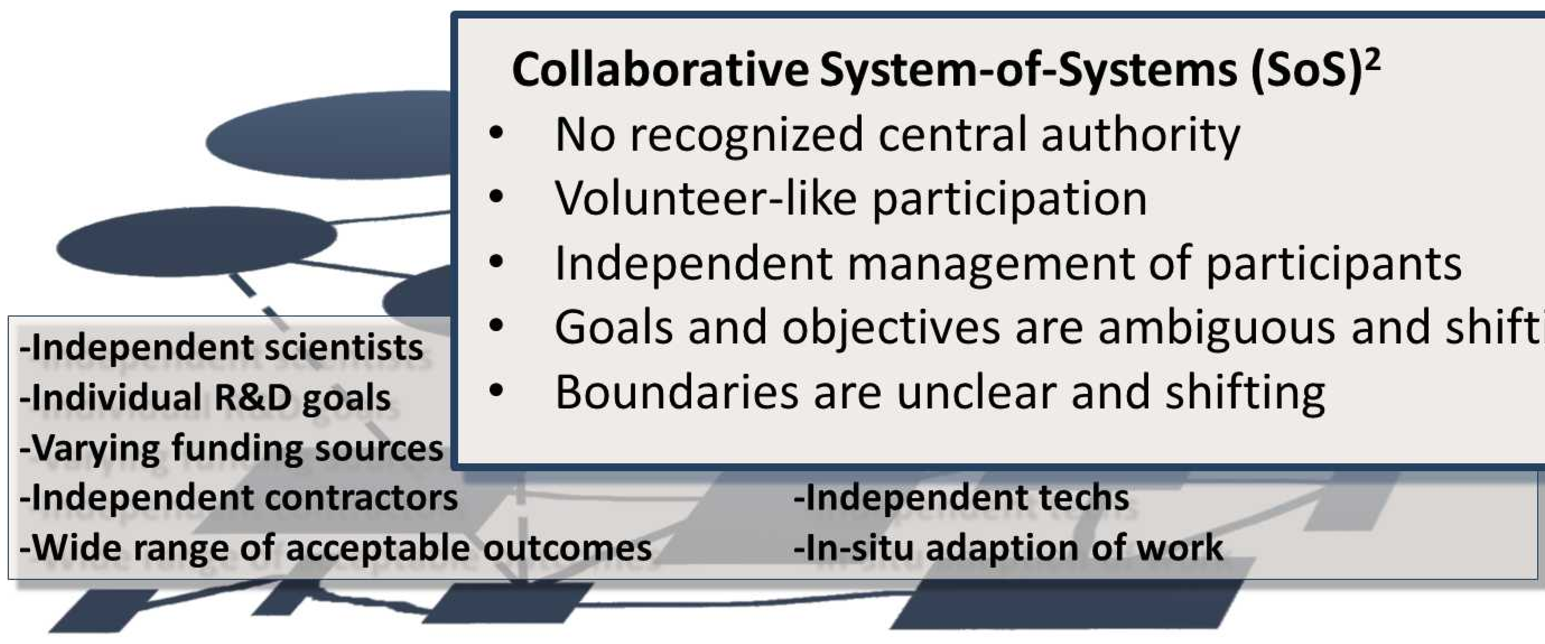
Emergent Knowledge Processes (EKPs)[1]

- Intellectual activities
- Expert knowledge
- Diverse people in unstructured and unpredictable combinations

-Plasma Physics
-Hydrodynamics
-Laser Technologies
-Dynamic Material Properties

-Mechanical Engineering
-Electrical Engineering
-Atomic Spectroscopy

-Real-time controls
-Highly specialized techs
-Highly specialized scientists



Collaborative System-of-Systems (SoS)[2]

- No recognized central authority
- Volunteer-like participation
- Independent management of participants
- Goals and objectives are ambiguous and shifting
- Boundaries are unclear and shifting

-Independent scientists
-Individual R&D goals
-Varying funding sources
-Independent contractors
-Wide range of acceptable outcomes

-Independent techs
-In-situ adaption of work

Problem

On a given experimental day, individual participants would like to plan their own work according to "how things are going" among complex and relatively unstructured interplay of personnel and equipment.

Challenges to determining "how things are going"

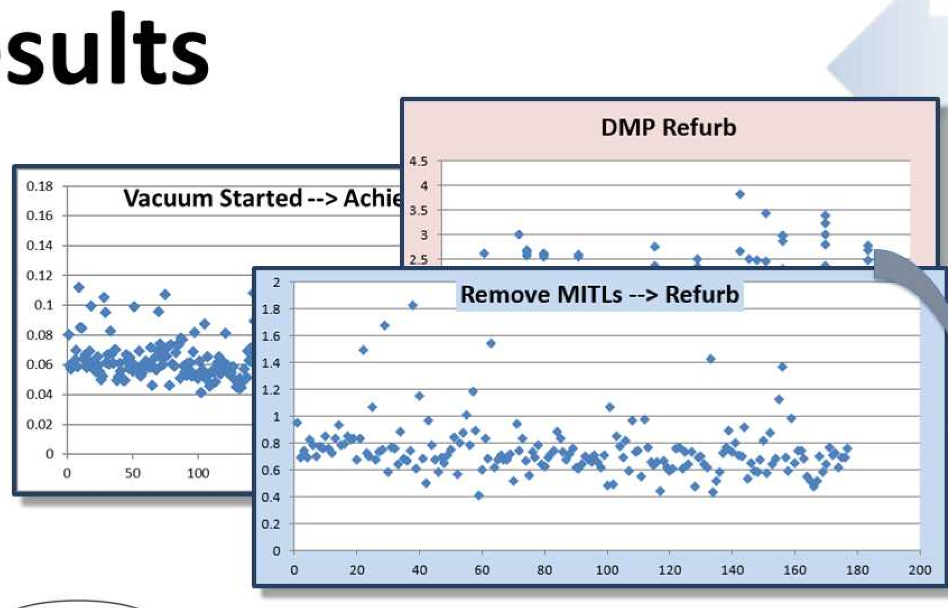
EKP / SoS

- Novel, rapid-change R&D work
- In-situ adaptation of participants
- Collaboratively emergent behavior
- Constrained, dynamic resource availability
- Other attributes of EKPs and SoS

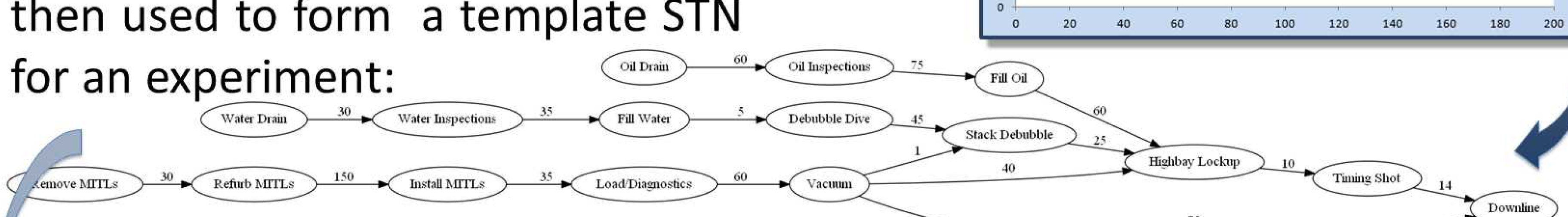
"When should I show up?"
"What time will Activity X happen?"
"What time should I be available?"
"How long do I have?"

Results

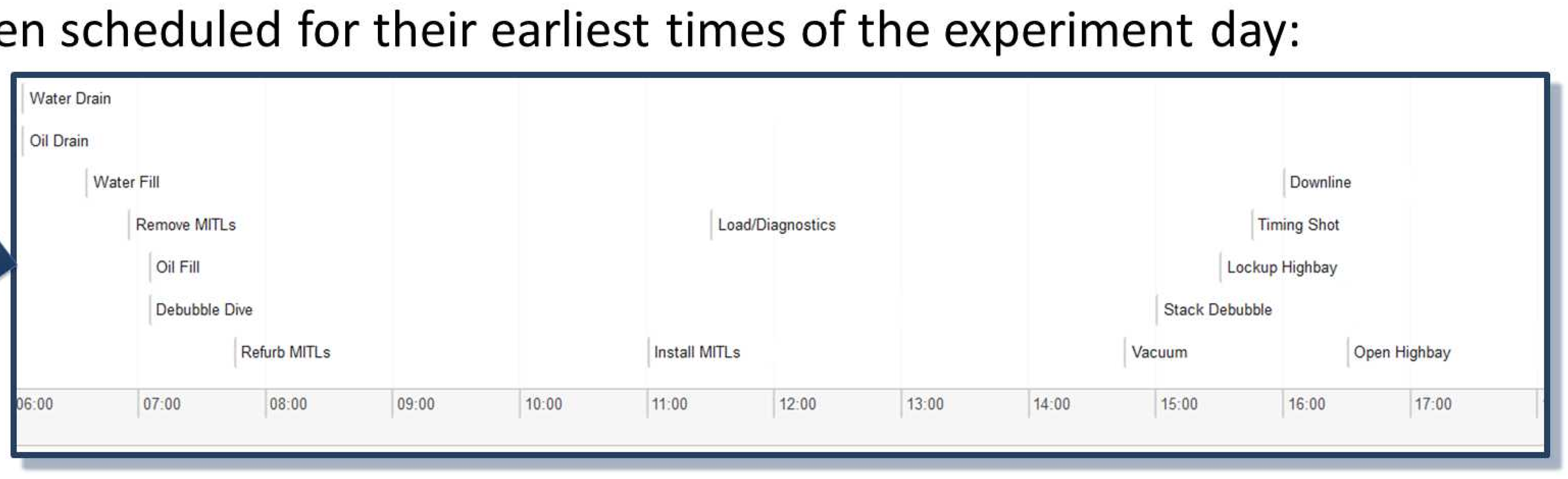
Thousands of historical data points from regular activities provided minimum time intervals:



The minimum intervals were then used to form a template STN for an experiment:

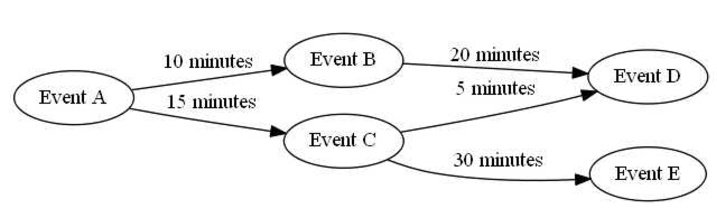


Where historical data is not available (e.g. novel activities), minimum durations are derived from optimistic values. Experimental activities are then scheduled for their earliest times of the experiment day:



Earliest times can then be communicated to participants to encourage checking in at that time. As the day progresses, activities may move right on the timeline, which does not invalidate the earliest time provided.

Method



Simple Temporal Networks (STNs)[3] define time intervals between events to construct a directed acyclic graph that allows automated scheduling and temporal reasoning about the timing of events.

Method: use an STN to determine earliest times of activities, similar to mass transit sociotechnical systems (e.g., buses, planes), where check-in times are provided to coordinate independent entities.

Why consider *earliest* times of activities instead of "likely" times?

	"Likely" time	*Earliest* time
Subjectively interpreted[4]	X	
Often wrong, fostering blame	X	
Inefficient for coordination[5]	X	
Minimal information requirements		X
Encourages availability		X
Seldom wrong, fostering trust		X
Robust to unexpected delays		X
Robust to rapid process evolution		X

1 Markus, M. L., Majchrzak, A., & Gasser, L. (2002). A design theory for systems that support emergent knowledge processes. MIS quarterly, 179-212.
2 Maier, M.W. (1996). Architecting principles for systems-of-systems. In INCOSE International Symposium (Vol. 6, No. 1, pp. 565-573).
3 Dechter, R., Meiri, I. and Pearl, J. (1991). Temporal constraint networks. Artificial intelligence, 49(1-3), pp.61-95.
4 Wark, D. (1964). The Definition of Some Estimative Expressions. *Studies in Intelligence, 8(Fall)*, 64-80.
5 Savage, S. L., & Markowitz, H. M. (2009). *The flaw of averages: Why we underestimate risk in the face of uncertainty*. John Wiley & Sons.

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NNSA National Nuclear Security Administration
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