Assurance Cases for Design Analysis of Complex System of Systems Software

Presented at
AIAA Infotech@Aerospace Conference
Software Assurance Session
8 April 2009

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Problem: SoS are Common, but Difficult

Huge systems of systems (SoS) development efforts

- Have become quite commonplace as aerospace/defense solutions
  - The Global Earth Observation System of Systems (GEOSS)
  - The US Army's Future Combat Systems
  - The US Coast Guard's Deepwater
  - Etc.
- Exhibit extreme complexity – they're hard to understand in detail
- Are difficult, even impossible, to test adequately using traditional methods
- Use software as an enabler of SoS functionality

Often, SoS elements are dispersed geographically, adding complexity and making predictability of behavior difficult

How can project management, stakeholders, and decision makers achieve some reasonable level of confidence that software for a large-scale, dispersed SoS will meet *operational needs*, even before development of much of the software?

Recent Experience Led to Assurance Case Use

An SEI team was tasked with answering this question in the face of:

- *the* software design was actually *many* software designs documented in many places and with a *tremendous* volume of data
- the designs were not yet complete and would not be complete until after many production decisions had to be made
- the need to relate the software to operational needs
- the desire to base conclusions as much as possible on *actual data* rather than on optimistic plans and confident assertions

Constraints

- short time frame: a project level review had a hard deadline
- limited availability of personnel, all with varying levels of domain knowledge

We Had to Relate Operational Needs to Software

The top-level SoS requirements were expressed in military terms.

- A requirements analysis would be repeating work already done
- Errors in requirements traceability could skew the entire analysis

We decided against re-casting the operational needs in terms of software and instead analyzed the software contributions to the definitive characterization of those needs—the Key Performance Parameters (KPPs).

The size of the analysis space, the complexity of the task, and the desire to leverage data suggested an *assurance case* approach

- The analysis was a structured decomposition of each KPP into more precise statements that could be more readily assessed in terms of evidence.
  - Challenge: be logical and consistent but avoid accumulating too much detail
  - Use engineering judgment to leap from higher-level concepts to lower-level ones

An Assurance Case is a Structured Argument

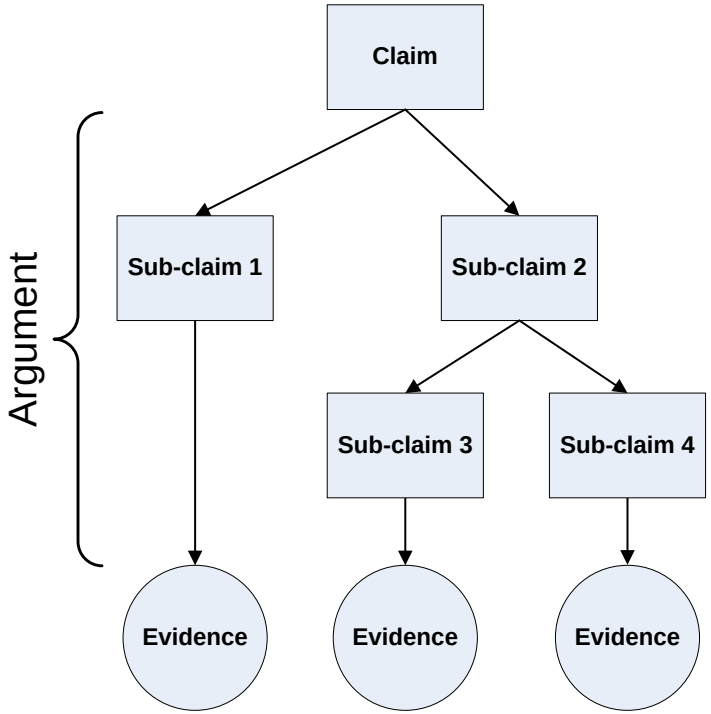
An assurance case

- is a generalization of a safety case
- presents an argument (similar to a legal case) that a system has or satisfies some property in a given context
- requires claims, evidence, and an argument linking evidence to claims
- should be sound and complete to justify belief in the main claim
- should be based on objective evidence

Goal Structuring Notation (GSN)

- graphically presents the *argument* by showing how *claims* are broken down into *sub-claims* until arriving at a sub-claim supported by *evidence*.

For our purposes, we used assurance cases to demonstrate that a SoS software design supported each of the SoS KPPs, as in the claim "The SoS will satisfy KPP k"



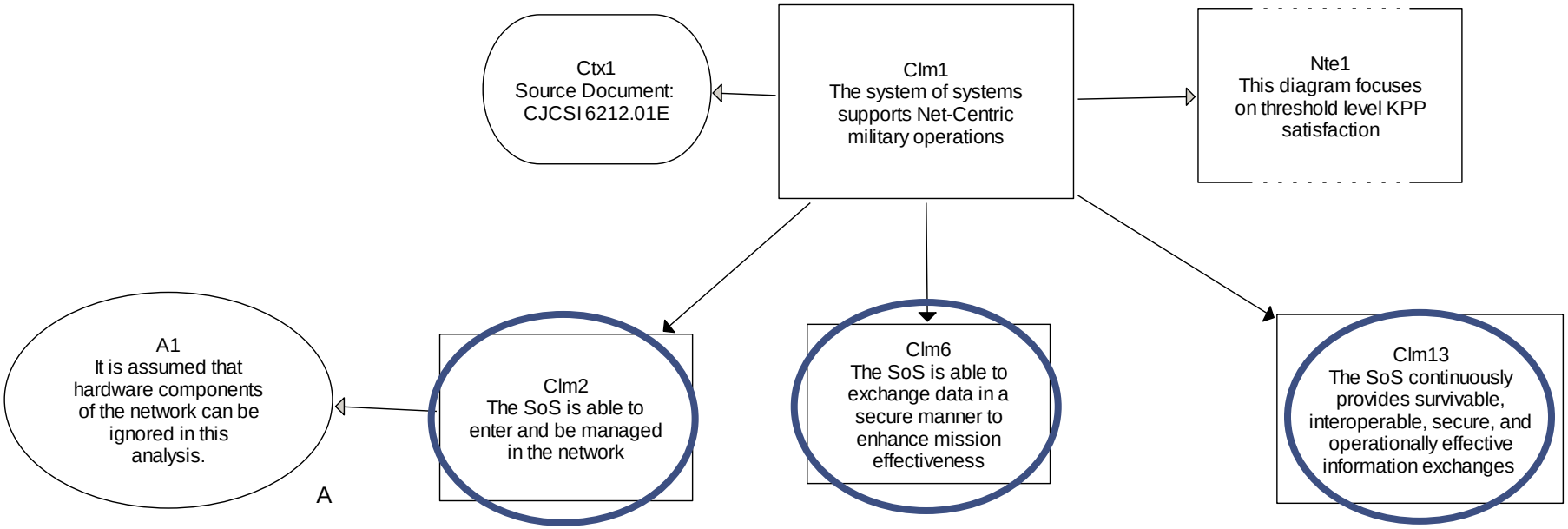
An Example

Assume we're developing a SoS for a DoD project

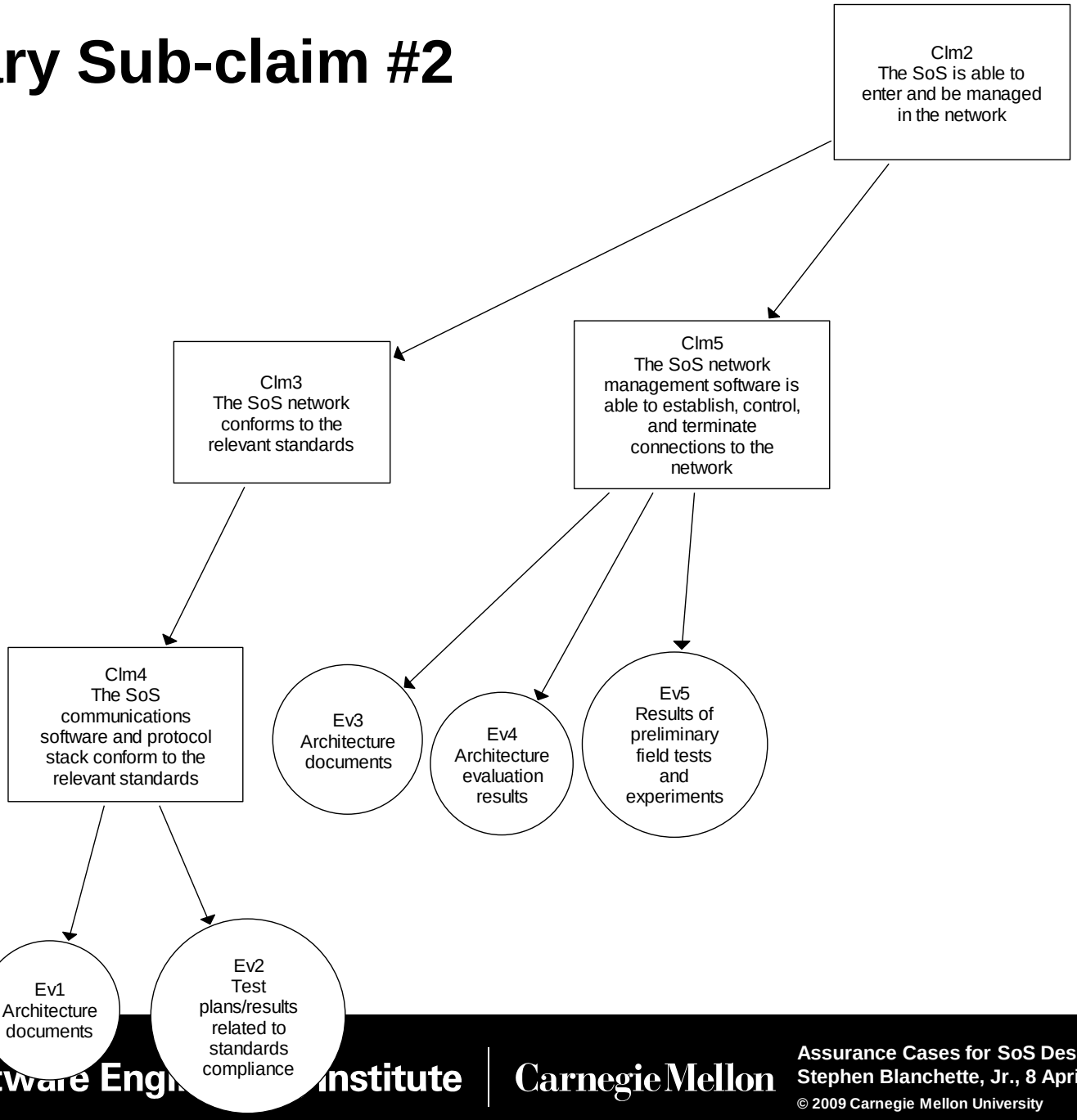
- The SoS must exchange information with other systems
  - Our SoS is subject to the Net Ready Key Performance Parameter (NR KPP):
    - **The system...must support Net-Centric military operations**. The…system…must be able to enter and be managed in the network, and exchange data in a secure manner to enhance mission effectiveness. The…system…must continuously provide survivable, interoperable, secure, and operationally effective information exchanges to enable a Net-Centric military capability.

Chairman of the Joint Chiefs of Staff Instruction, "Interoperability and Supportability of Information Technology and National Security Systems," CJCSI 6212.01E, 2008.

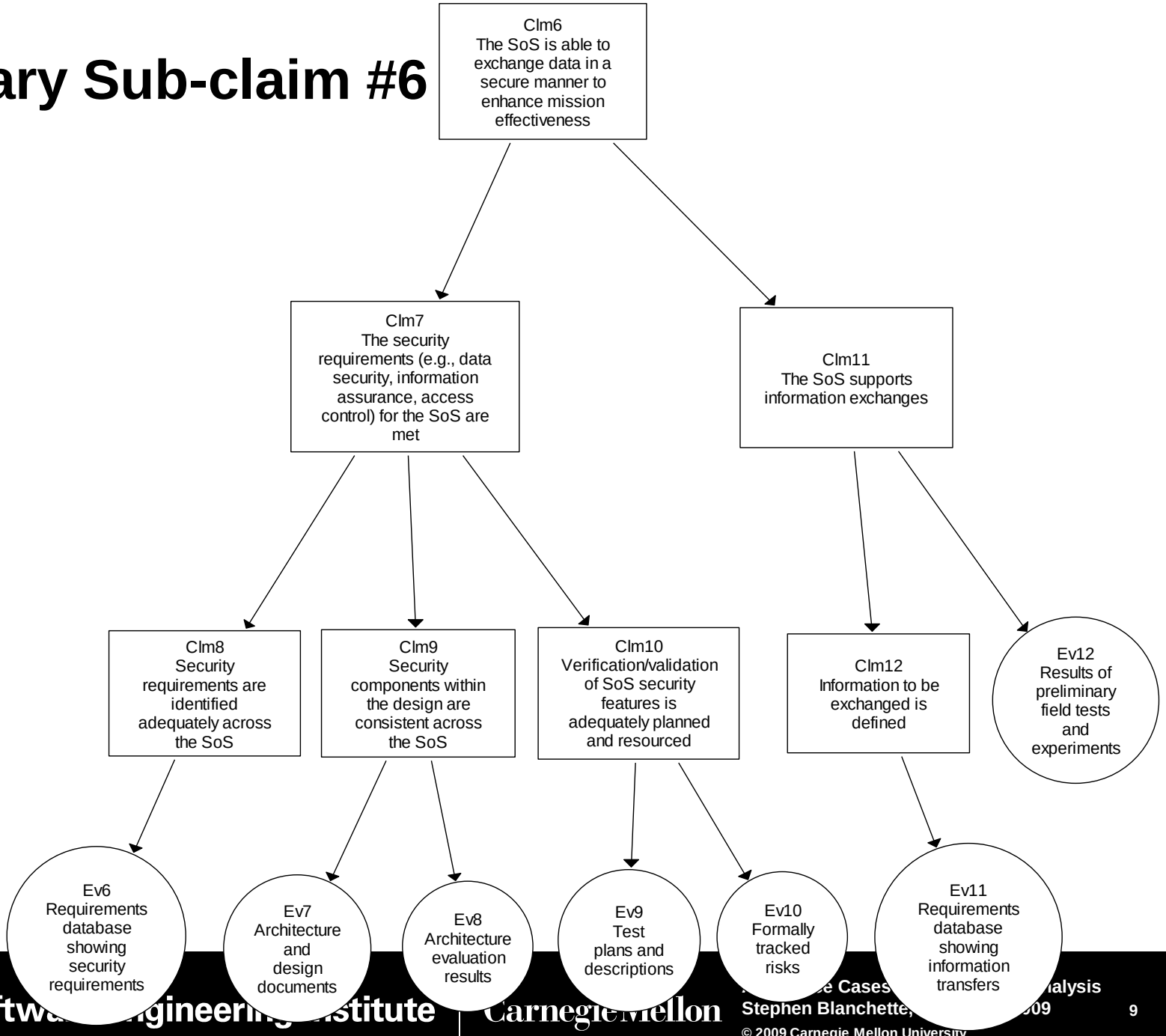
We Can Express the NR KPP Diagrammatically



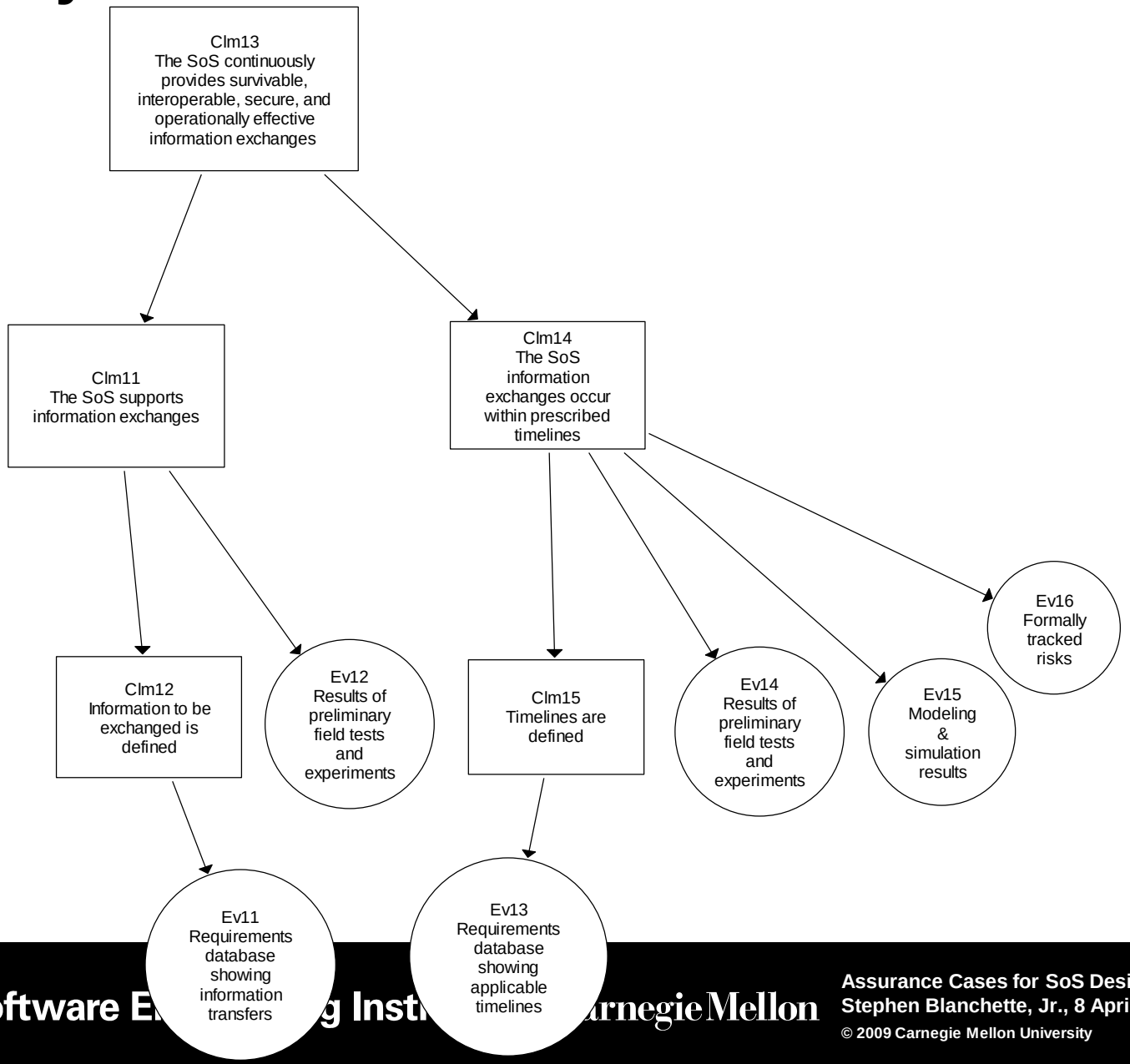
Primary Sub-claim #2



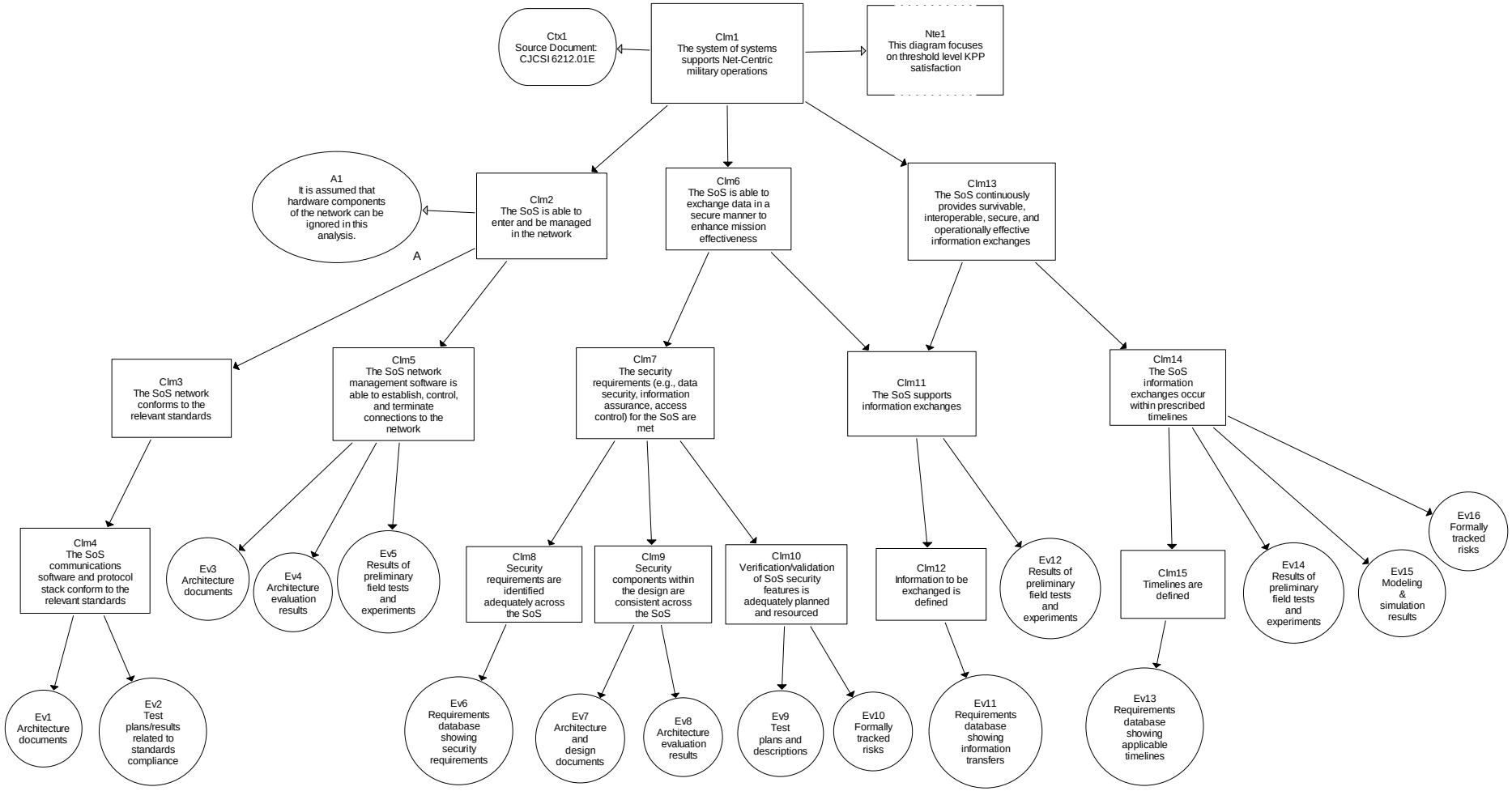
Primary Sub-claim #6



Primary Sub-claim #13



A Diagram Helps Visualize the Completed Case



Logic Should Hold…*Even Without the Diagram*

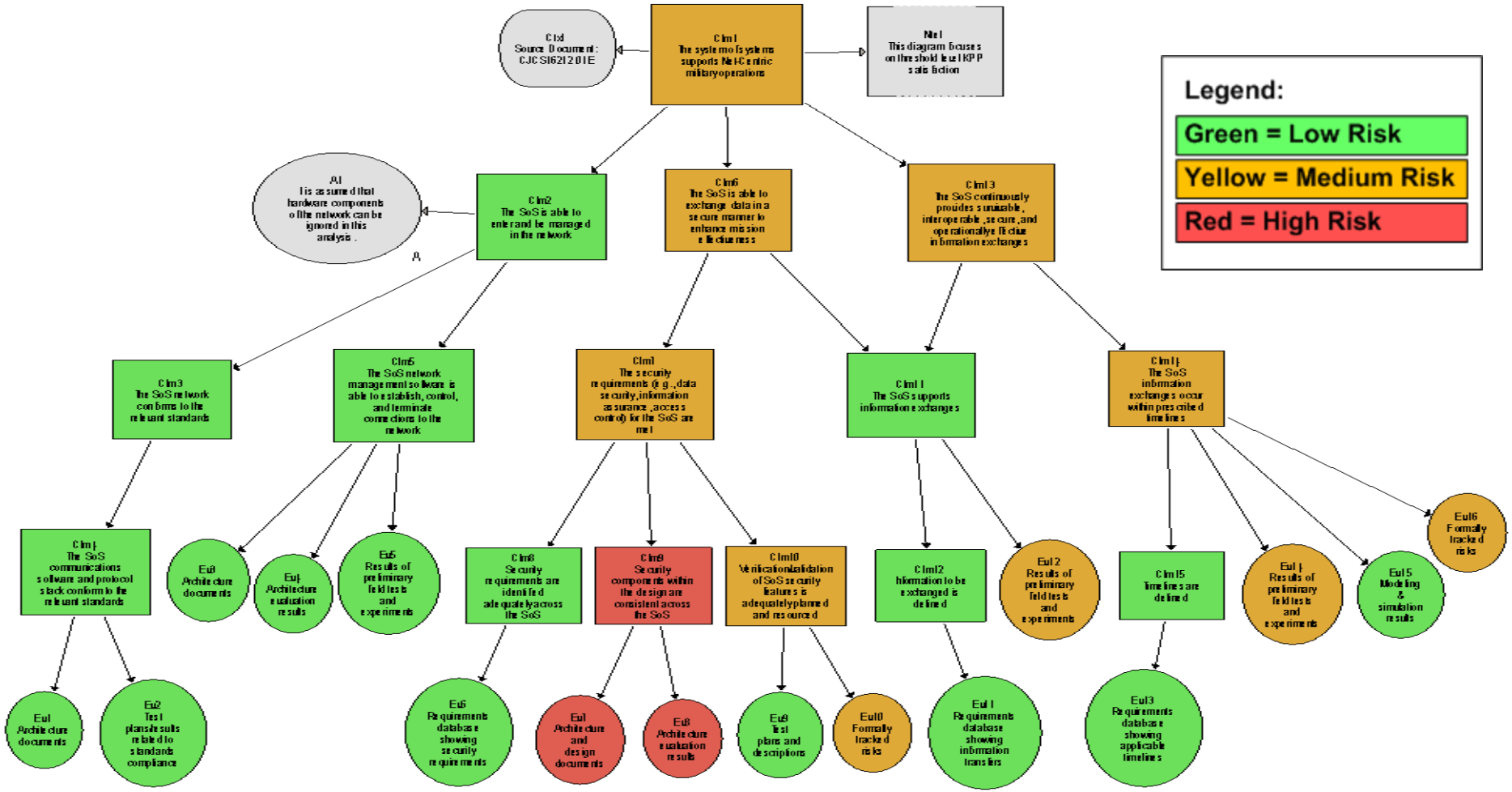
Scoring Can be Used to Express Risk

First, Develop Scoring Rules

For Evidence	
Green	Evidence is complete and adequate
Yellow	Evidence is incomplete or planned for the future
Red	Evidence is complete but inadequate, planned but now late, or non-existent
For Claims	
Green	All lower-level claims and supporting evidence are green
Yellow	Some lower-level claims and supporting evidence are a combination of yellow and red
Red	All, or an overwhelming majority of, lower-level claims and supporting evidence are red

Then, Work Upward from Evidence…

Scored Diagram Provides a Roadmap…



Quality of the Evidence Drives Assessment of Claims…and Relative Risk

Assurance Cases are Helpful in the SoS Space

Assurance cases gave us a way of organizing a nebulous task and gave us a means of selecting among innumerable artifacts to study. They brought order to complexity.

- Due to time constraints we had to focus on big picture risks
- A more thorough analysis might have identified additional risks or strong points

The assurance case technique is a powerful tool for analyzing large and complex SoS software design.

- It provides a means of taking a crosscutting look at SoS
- It gives managers answers about design progress that are rooted in facts and data instead of opinions based upon hope and best intentions.

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