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Talking About Concerns . . .

James D. Herbsleb
School of Computer Science
Carnegie Mellon University

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What is Modularity?

- Thanks, Mary!
- Thanks, Dick!

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Why Modularity?

- **Software** modularity does not matter
- . . . at all
- Except . . .
  - To the extent it modularizes **work**
- **Work** modularity aids human understanding
- **Work** modularity simplifies coordinating people and teams

Parnas:
Expected Benefits of Modularity

- Reduce need for coordination
  - “separate groups would work on each module with little need for communication”
- Simplify comprehension
  - “it should be possible to study the system one module at a time”
- These effects lower the cost of change
  - “it should be possible to make drastic changes to one module without a need to change others”

Parnas, D. L. On the Criteria to be Used in Decomposing Systems into Modules. *Communications of the ACM*, 15, 12 (1972), 1053-1058, p. 1054.

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Vision . . .

- “a vivid mental image; ‘he had a vision of his own death’” *
- “an Explanation of Life Founded upon the Writings of Giraldus and upon Certain Doctrines Attributed to Kusta Ben Luka” *
- “a thought, concept, or object formed by the imagination” **
- “direct mystical awareness of the supernatural“ **

*wordnetweb.princeton.edu/perl/webwn
**Merriam-Webster Dictionary

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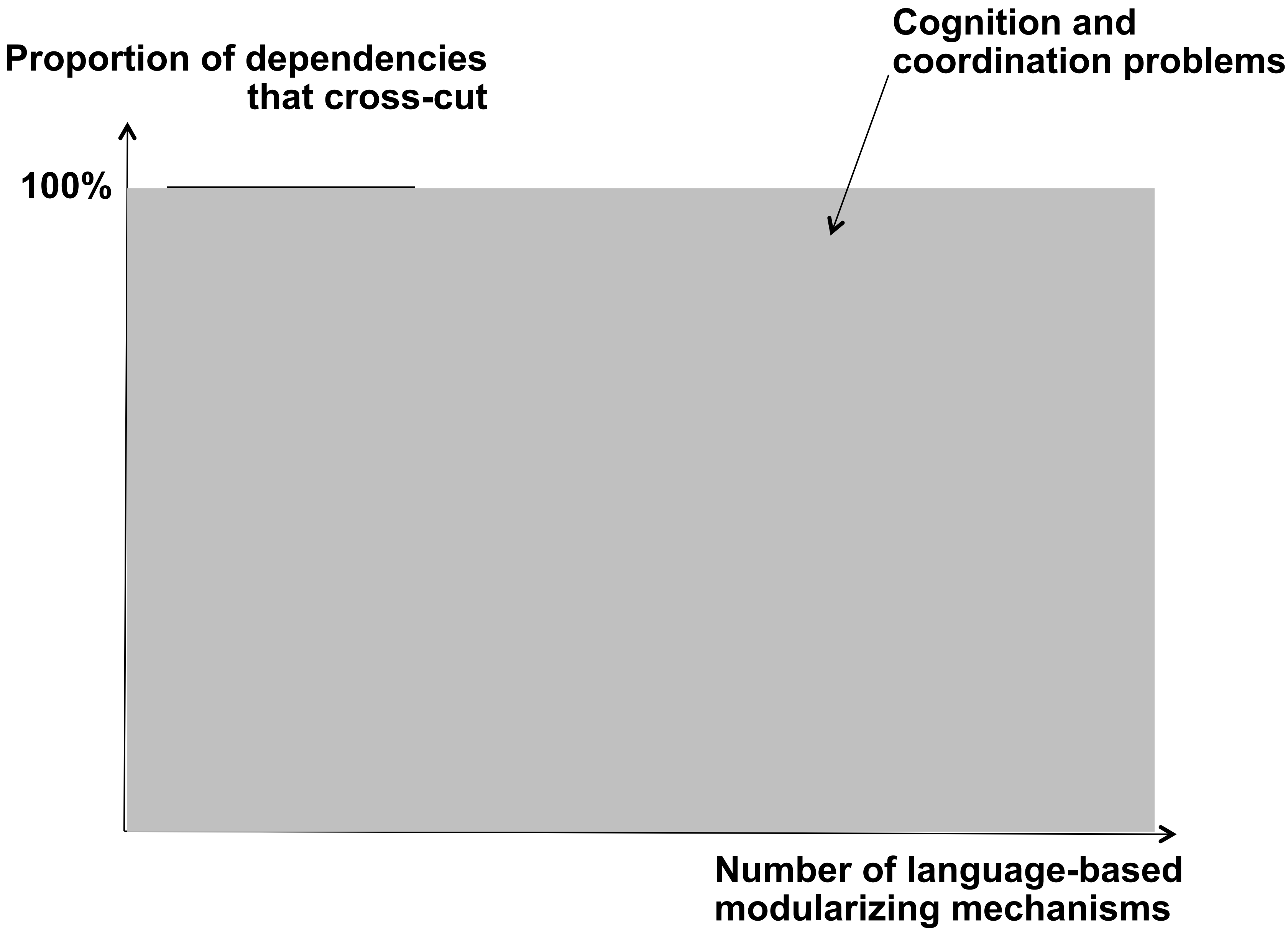
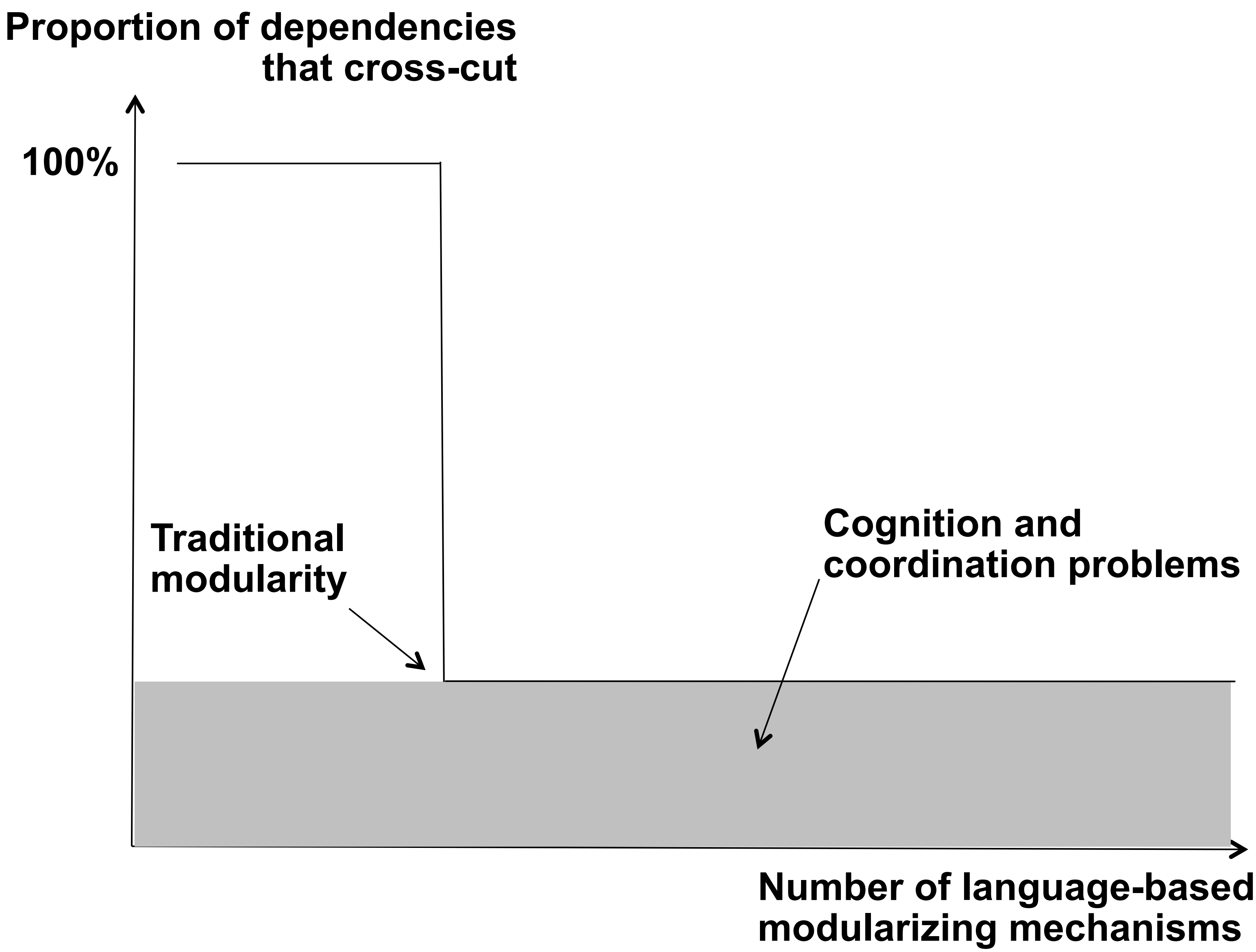
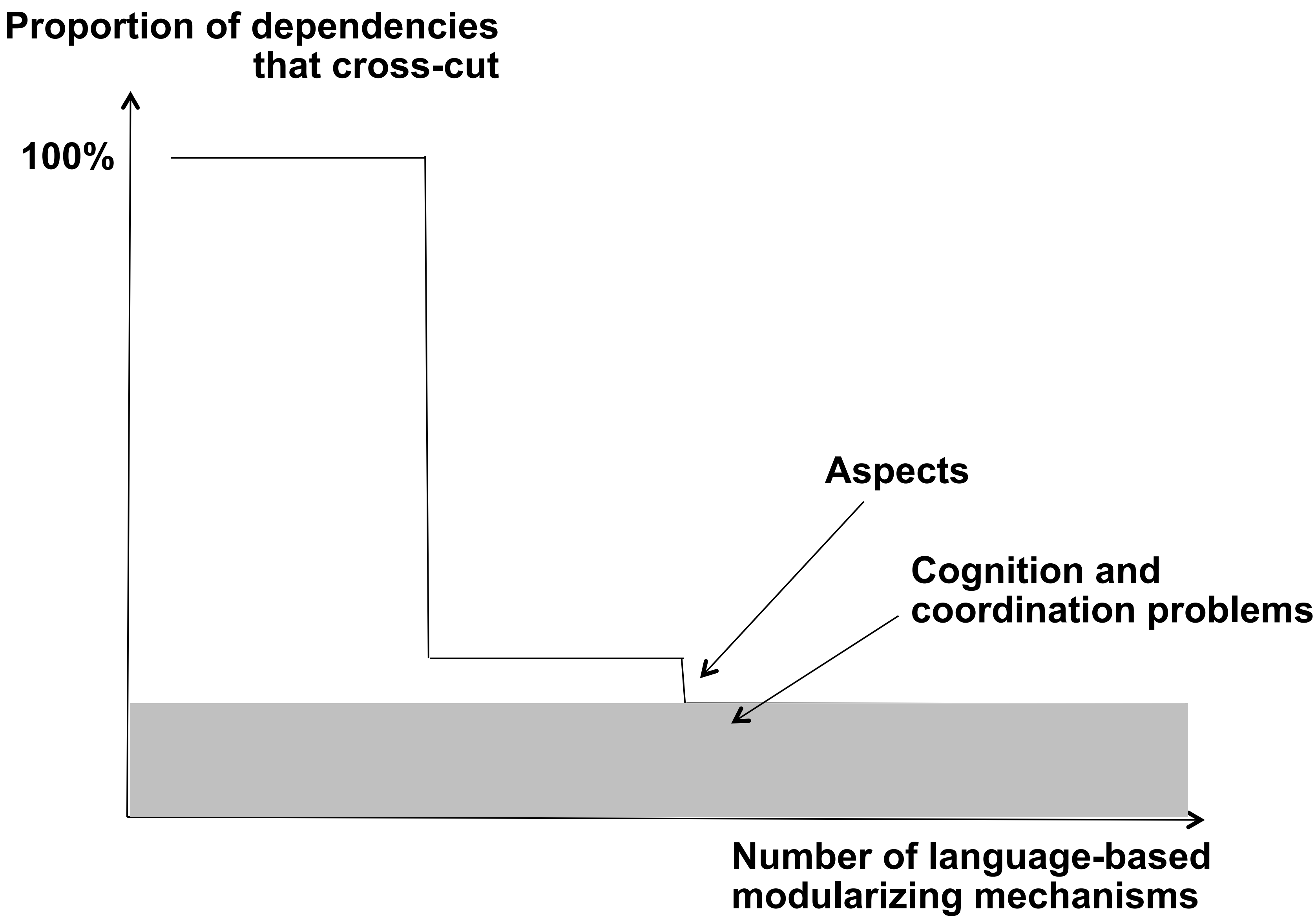

Cognition and
coordination problems
Proportion of dependencies
that cross-cut
100%
Number of language-based
modularizing mechanisms


Proportion of dependencies
that cross-cut
100%
Traditional
modularity
Cognition and
coordination problems
Number of language-based
modularizing mechanisms



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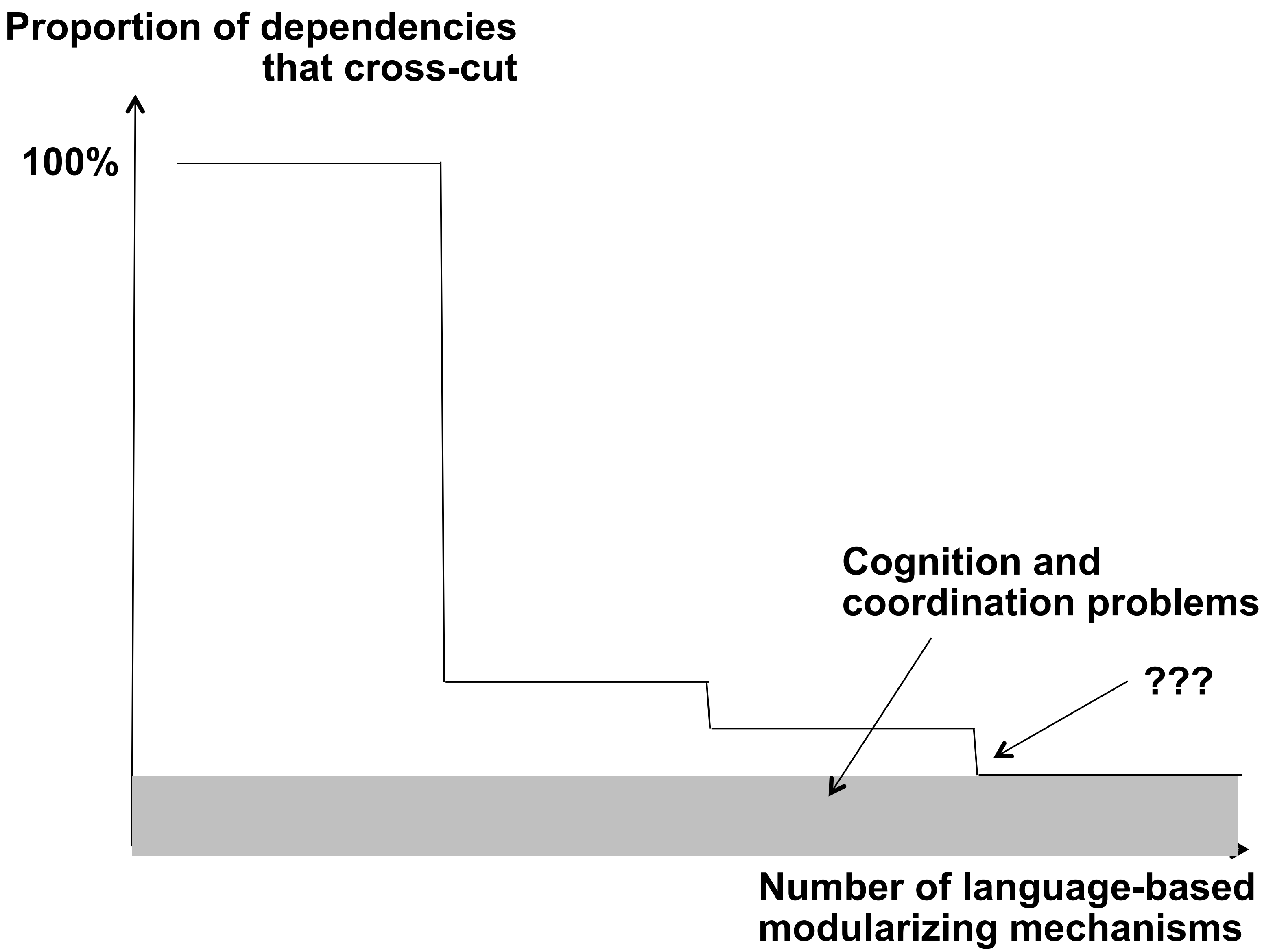
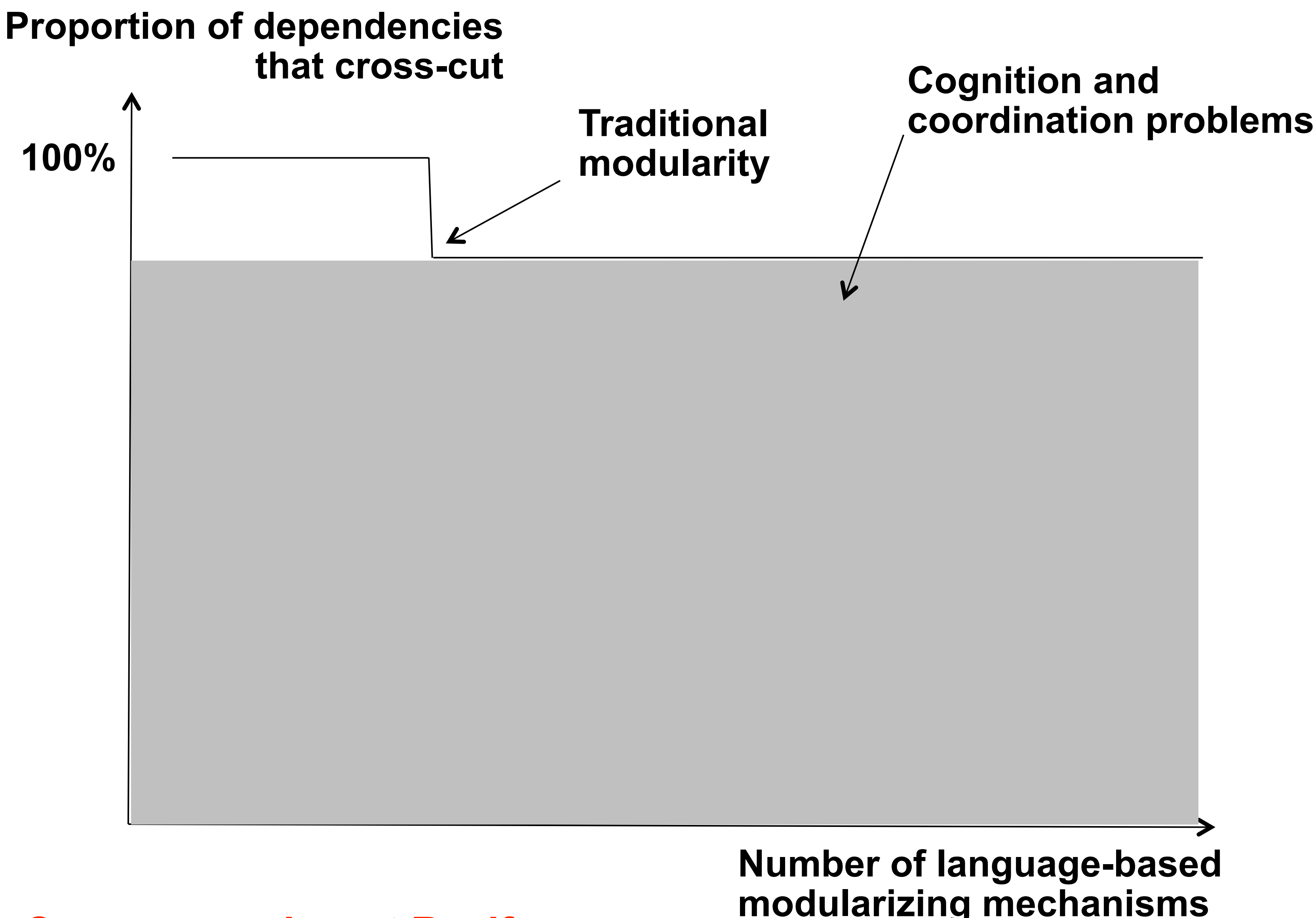

Proportion of dependencies
that cross-cut
100%
Cognition and
coordination problems
???
Number of language-based
modularizing mechanisms



Consensus view at Recife

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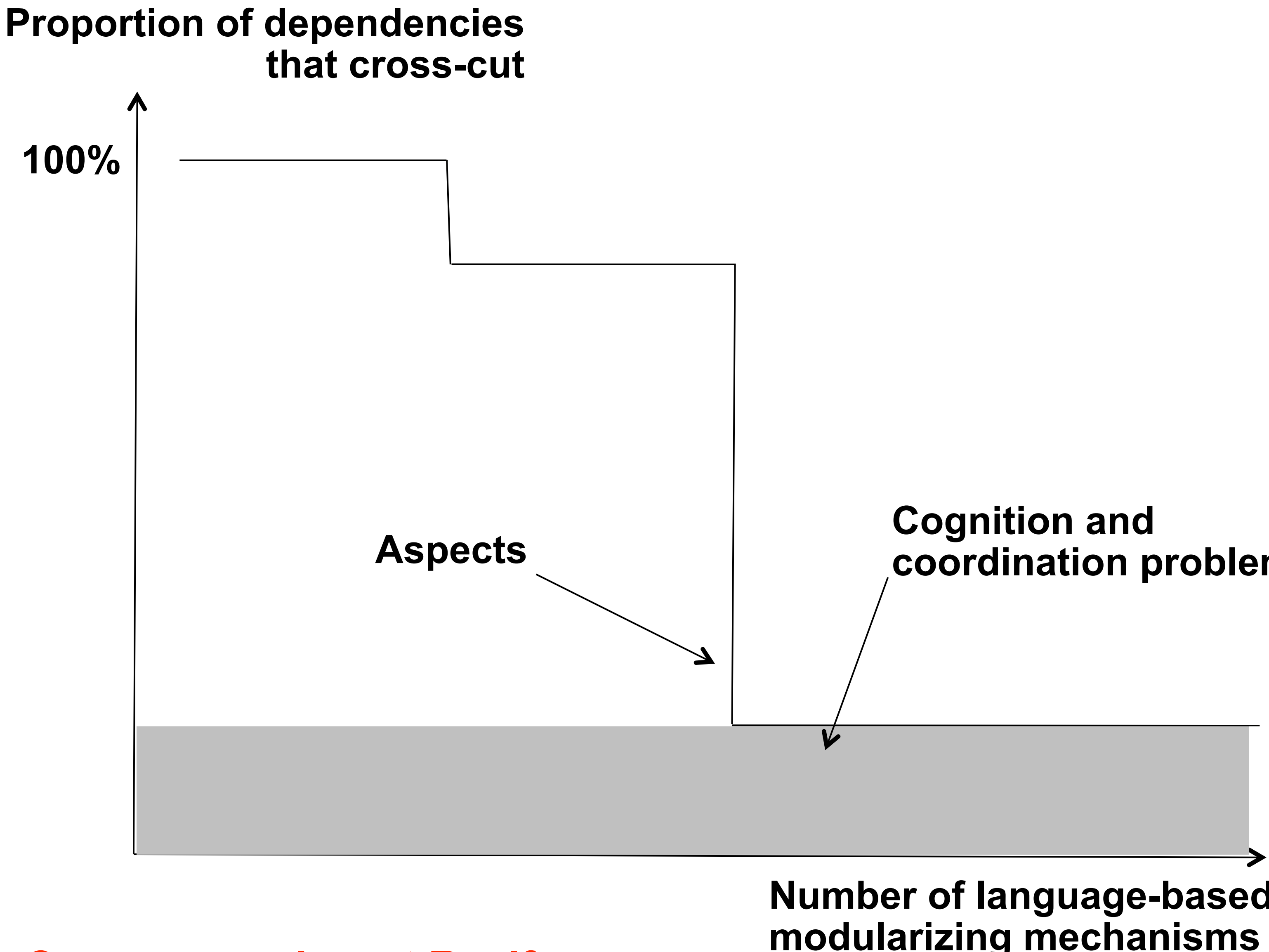
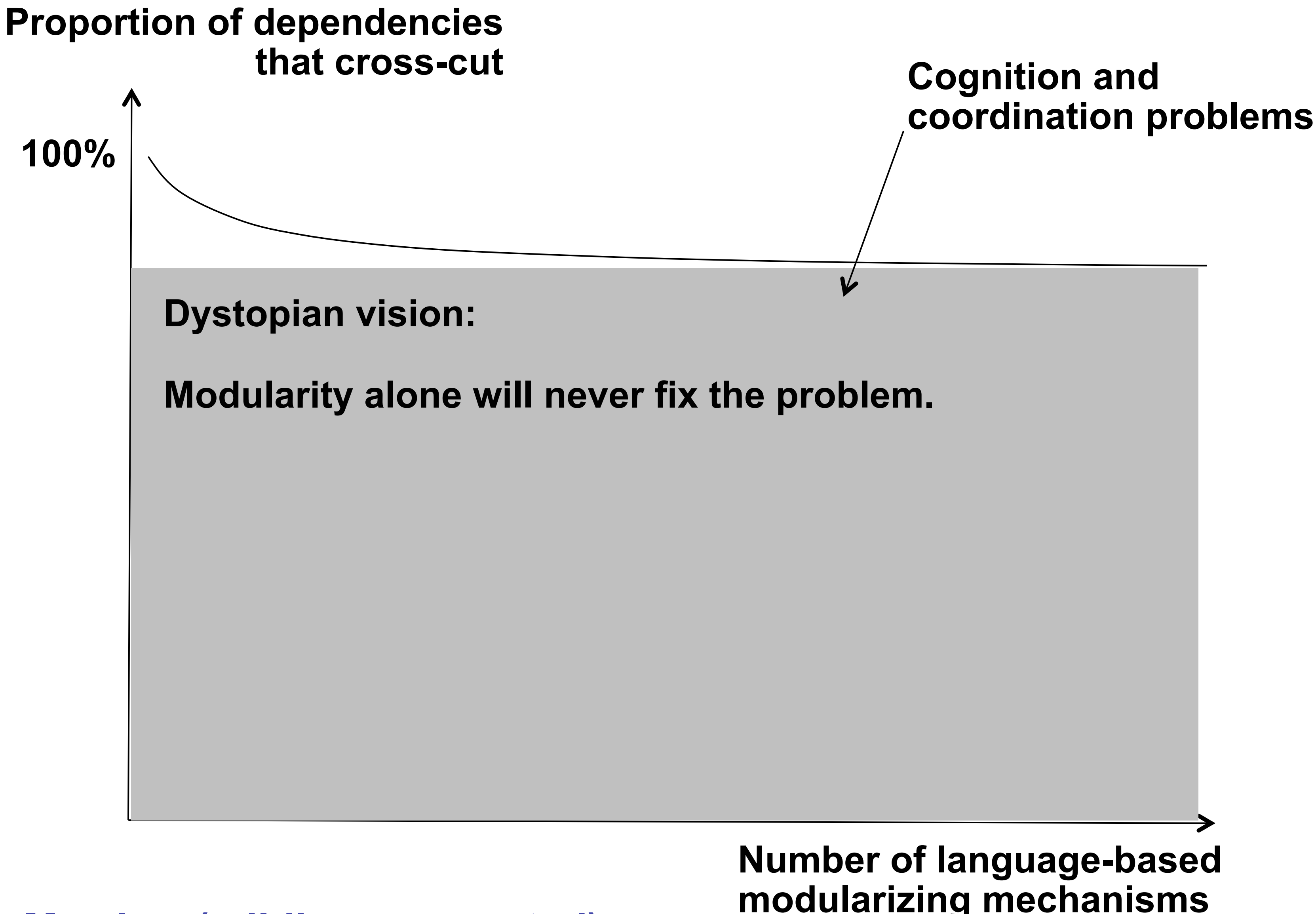


Consensus view at Recife



My view (mildly exaggerated)

Approaching the Gray Area . . .

- Organizational design, work assignment, and tools set up to bring the right dependencies to the attention of the right people so they can act appropriately

Two Examples . . .

- Organizational design and work assignment
  – Lessons from feature-driven development
- Using information from the environment
  – Learning from human activity

Feature-Driven Development

- Unit of functionality in end-user terms
- Feature is the unit of development managed by a project
- Features tend to cut across traditional software entities
- Work often overseen by “feature manager”
- Developers associated with component, assigned to work on particular features

The Study

- Setting
  - Software for automotive navigation system
  - 1195 features
  - 32 months of activity
  - 179 engineers in 13 teams
  - 1.5 M LOC, 6789 source files, 107 architectural components
  - Organization had 5 years of prior experience with feature-driven development
- Architects prepare feature development specification

What Causes Integration Failure?

	Model I	Model II	Model III	Model IV
Time	0.992*	0.990*	0.990*	0.989*
Average Component Experience (log)	0.487*	0.984+	0.741+	0.754
Changed LOCs		1.021	1.089	1.063
Concentration of Changed LOCs		1.045	1.028	1.036
Number of Dependencies (log)		1.107*	1.091*	1.091*
Concentration of Number of Dependencies		1.032**	1.046**	1.078**
Number of Groups			1.101*	1.051*
GSD			13.924**	14.964**
Feature Owner Belongs to Highly Changed Component			0.789	0.396
Feature Owner Belongs to Highly Coupled Component			0.839**	0.819**
Concentration of Changed LOCs X *F. Owner Belongs to Highly Changed Component*				1.032
Concentration of Number of Dependencies X *F. Owner Belongs to Highly Coupled Comp.*				0.977**
GSD X *Feature Owner Belongs to Highly Changed Component*				3.736
GSD X *Feature Owner Belongs to Highly Coupled Component*				0.926
Deviance of the Model	755.2	639.0	458.4	412.2
Deviance Explained	11.7%	25.3%	46.4%	51.8%

(+ p < 0.1; * p < 0.05; ** p < 0.01)

Odds Ratios from Regression Assessing Factors Driving Feature Integration Failures

From Cataldo, M. & Herbsleb, J.D. (2011). Factors Leading to Integration Failures in Global Feature-Oriented Development: An Empirical Analysis. *Proceedings, International Conference on Software Engineering* (to appear).

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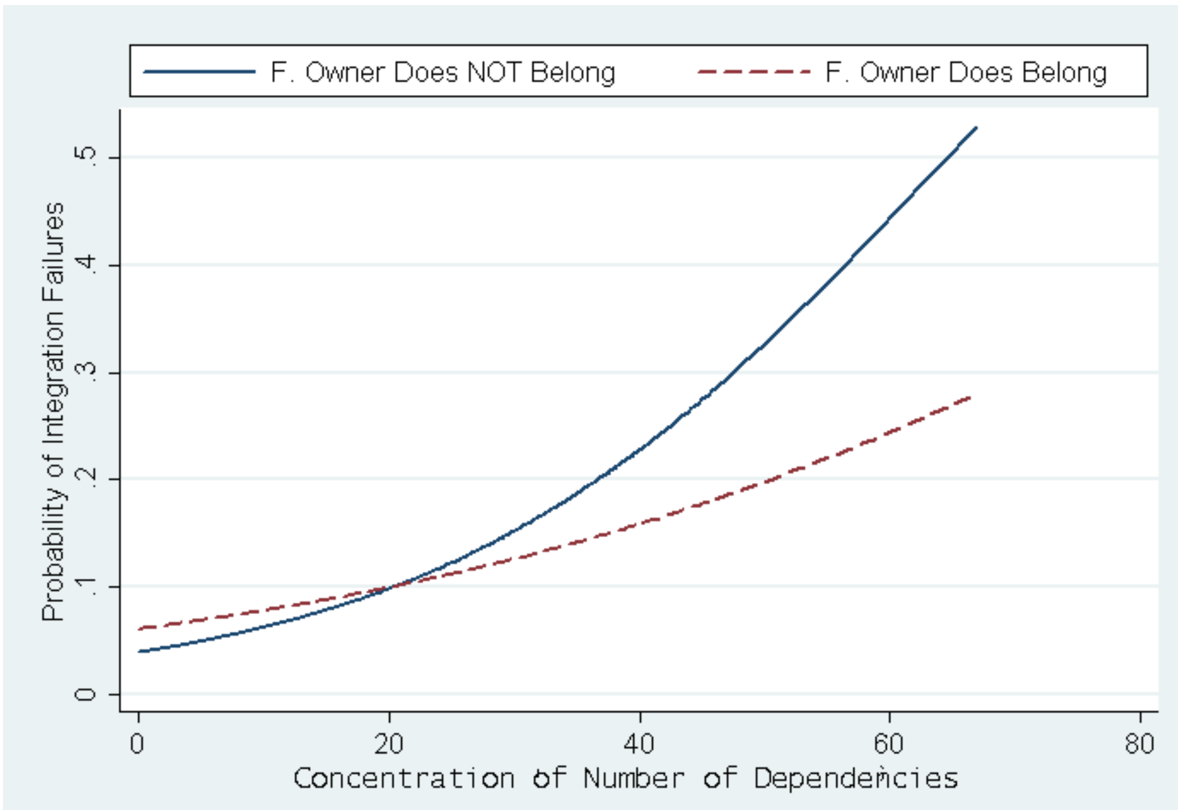
Ownership Matters!



From Cataldo, M. & Herbsleb, J.D. (2011). Factors Leading to Integration Failures in Global Feature-Oriented Development: An Empirical Analysis. *Proceedings, International Conference on Software Engineering* (to appear).

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Destructive Feature Interaction

	Model I	Model II	Model II
Time	0.981**	0.971**	0.964*
Failures in the Past 5 Weeks	2.127**	1.125*	1.011*
Changed LOCs	1.371**	1.201**	1.203**
Average Component Experience (log)	0.837+	0.997	0.908
Number of Groups	3.006**	4.037**	6.345**
Overlap Among Groups	0.943**	0.919**	0.901**
Same Feature Owner	0.876**	0.871**	0.852**
GSD	4.501**	2.509**	4.895**
Number of Cross-Feature Dependencies (log)		2.911**	4.938**
Number of Groups X Number of Cross-Feature Dependencies			0.607
GSD X Number of Cross-Feature Dependencies			0.799**
Deviance of the Model	12873.9	9413.1	8043.1
Deviance Explained	33.4%	51.3%	58.4%

(+ p < 0.1; * p < 0.05; ** p < 0.01)

Odds Ratios from Regression Assessing the Impact of Cross-Feature Interactions on Integration Failures

From Cataldo, M. & Herbsleb, J.D. (2011). Factors Leading to Integration Failures in Global Feature-Oriented Development: An Empirical Analysis. *Proceedings, International Conference on Software Engineering* (to appear).

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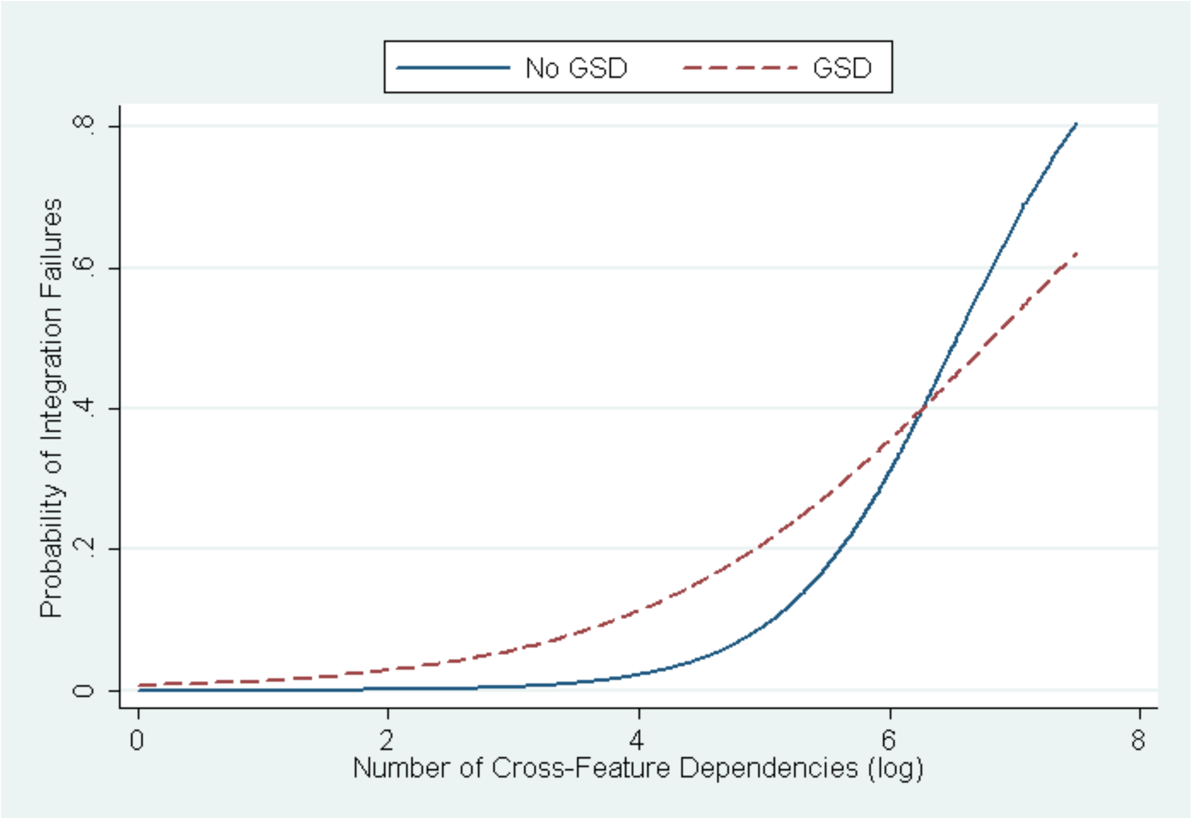
Co-location Doesn't Scale



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Broader Lessons

- Organizational arrangements matter!
- Effects can be quite large
- Effects often are not commonsensical

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Inferring Dependencies from Traces of Human Activity

- Prior work
  - Use files changed together as measure of dependencies
  - Can generate a measure of coordination requirements
  - Validated in a number of settings
- Can we generalize from “files changed together” to “entities discussed together”?

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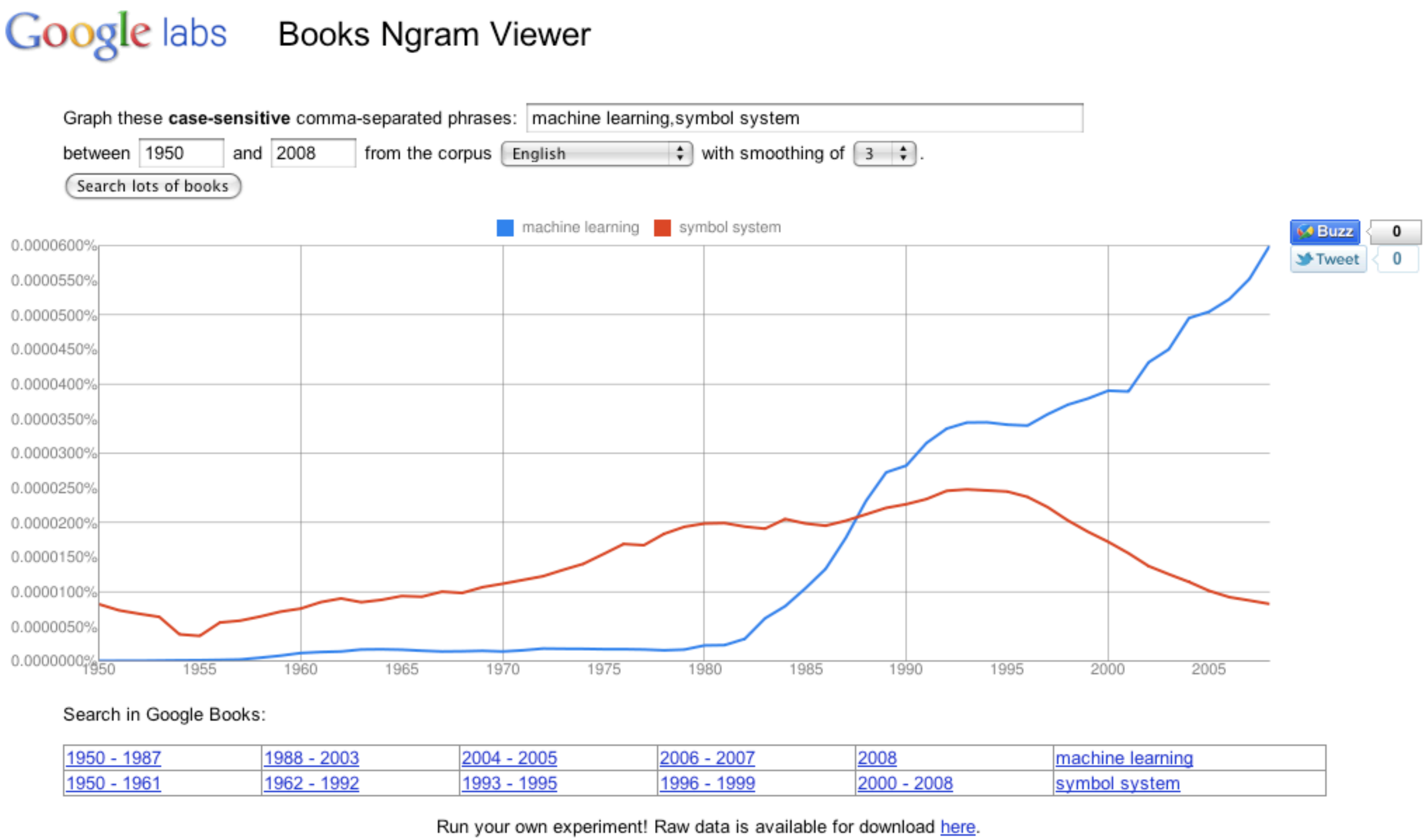
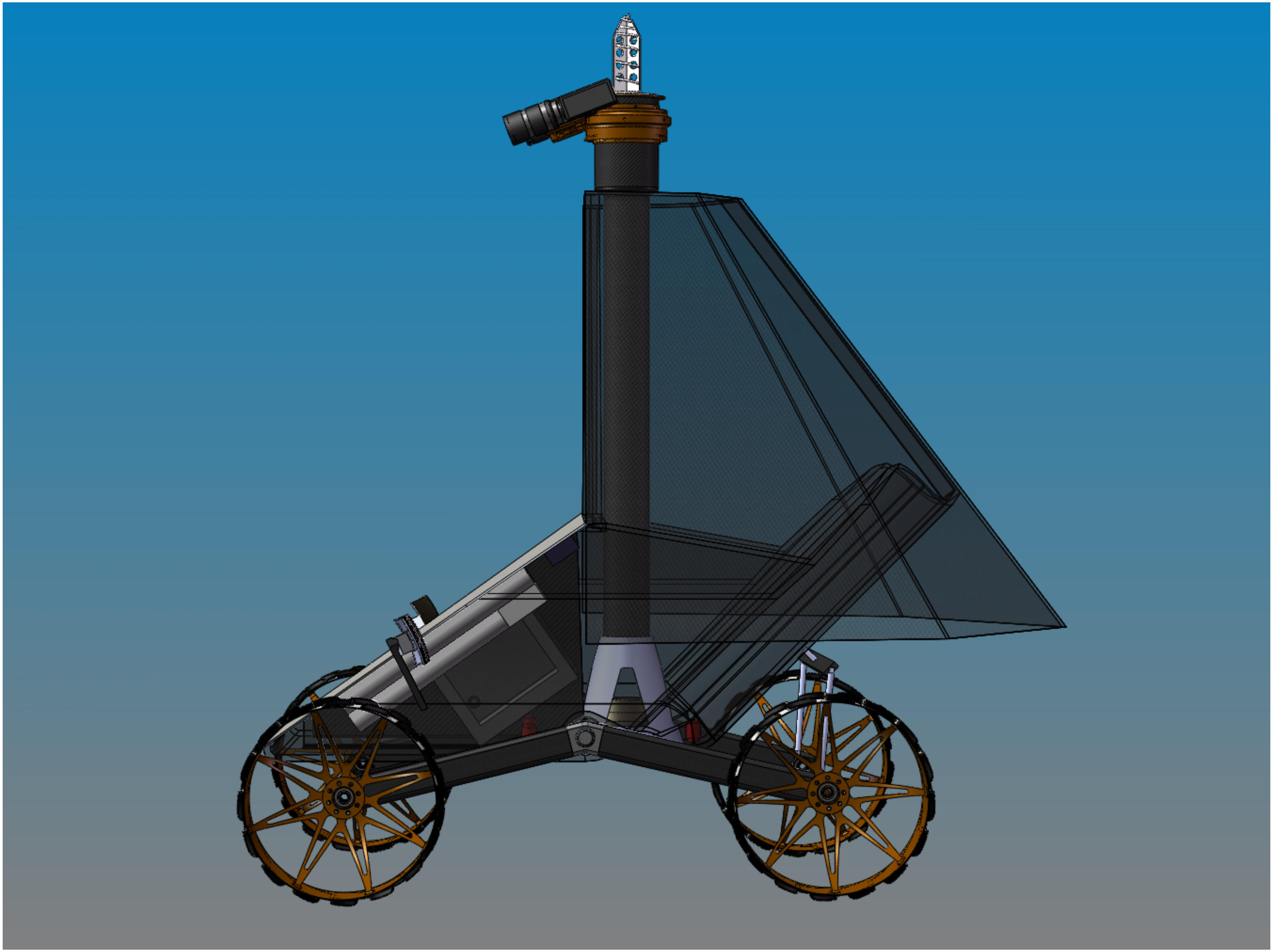
A Brief Digression/Analogy



Text Analysis: Field Robotics

- Project
  - Lunar X Prize competition



Text Analysis: Field Robotics

- Project
  - Lunar X Prize competition
- No automatically collected version or change data
- Constantly shifting component boundaries and interfaces
- Can we use text analysis to derive dependencies?

Steps

- Collected data
  - 25 all-hands meetings
  - About 10,000 words each
- Developed code book
  - 6 field robotics articles

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Code Book

Component:	Brief description:
Communications	Communications external to the robot, for control or mission, including operator interface.
External Relations	Acquiring external resources (incl. funding, parts, & purchasing), publicity, investor & media relations.
Internal Relations	Project/program management, HR, task assignments, training, collaboration tools, clarifying norms & expectations.
Mobility Effectors / Actuators	Effectors and actuators that propel the entire robot: e.g. tracks, wheels, shocks, & motors with associated firmware.
Mission Specific Effectors / Actuators	All other motors, gears, & moving parts that don't move the robot as a whole, e. g. camera mast rotation motor.
Perception software / computing	Software, and any dedicated hardware, for: terrain mapping, environmental modeling, and/or object detection. Camera/lens zoom, shutter, and focus control software.
Planning software / computing	Mission task planning, including the overall mission plan and computing resources for semi-autonomous execution.
Power	Includes batteries, solar cells, switches, power cables & controls.
Sensors	Camera; thermal, ultrasonic, tactile, radar/sonar range sensors; Inertial Measurement Unit, GPS, & any wiring or processing going from sensors to controls.
Shared / general computing	Includes general purpose processors / onboard computers (e. g. avionics box). Abbreviated "gpp."
Structure	Chassis, fasteners (e.g. Frangibolt, weld joints), radiator, payload, paints, reflectors.

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Steps

- Collected data
  - 25 all-hands meetings
  - About 10,000 words each
- Developed code book
  - 6 field robotics articles
- Manual coding of decision discussions
  - Tested inter-rater reliability
    - QAP correlations .80

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Text Pre-Processing

Step	Description
1	Removed contractions (e. g. changing "what's" to "what is").
2	Applied a Krovetz (dictionary-based) stemmer to covert terms into morphemes
3	Removed common English terms (e. g. 'the'), replacing them with placeholders ('xxx').
4	Removed punctuation.
5	Turned meaningful bigrams into unigrams (e.g. 'solar cells' became 'solar_cells').

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Steps

- Collected data
  - 25 all-hands meetings
  - About 10,000 words each
- Developed code book
  - 6 field robotics articles
- Manual coding of decision discussions
  - Tested inter-rater reliability
    - QAP correlations .80
- Created thesaurus

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Link Identification

- Co-occurrence of terms
- Human coding: same decision
- Selected sliding window size
  - Size 15 had best agreement with hand coding
  - Threshold established
- QAP correlations comparable to human-human agreement (~.8)
- Sets of links based on topics

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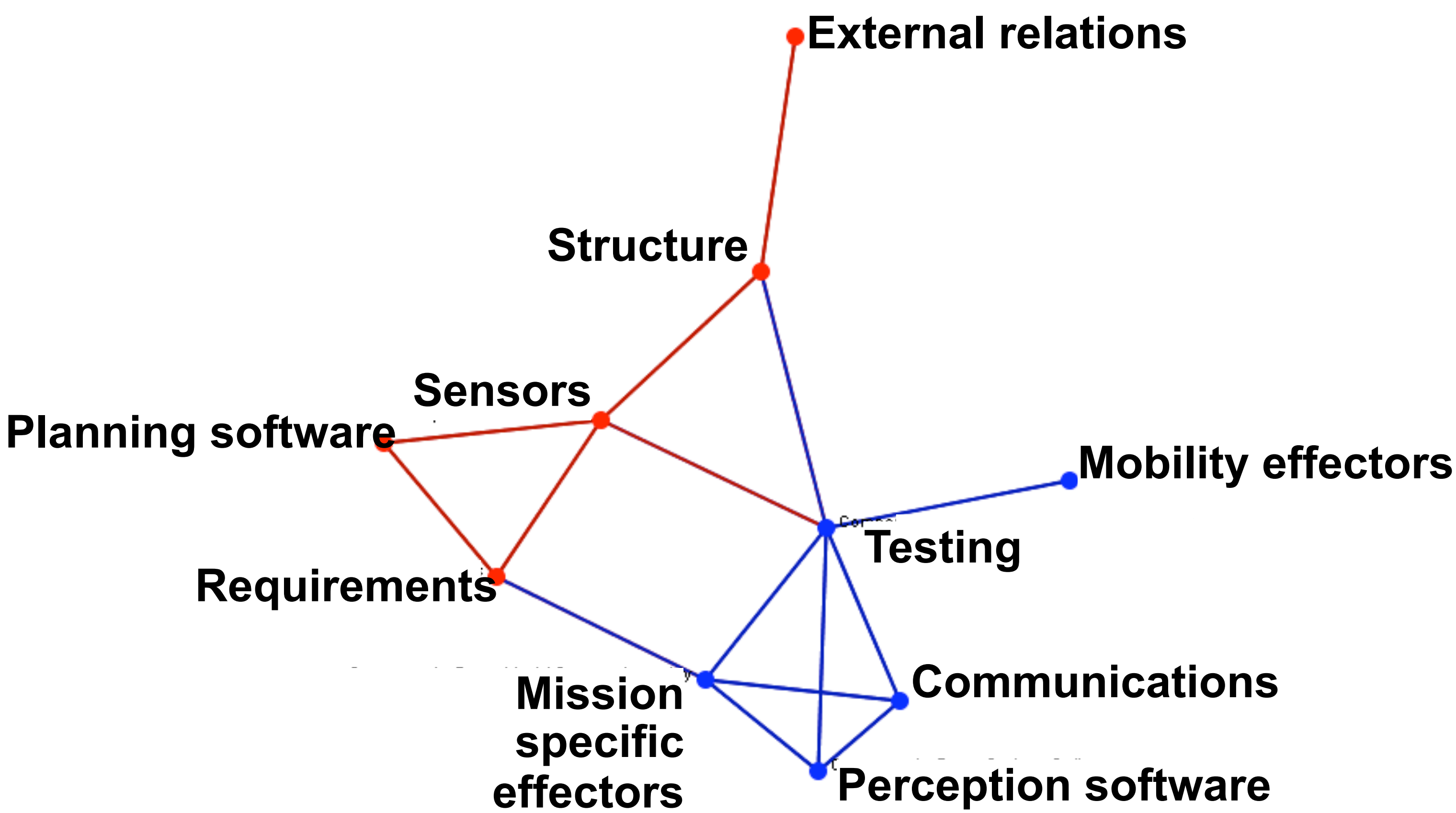
Optics


External relations
Structure
Sensors
Planning software
Mobility effectors
Testing
Requirements
Communications
Mission specific effectors
Perception software

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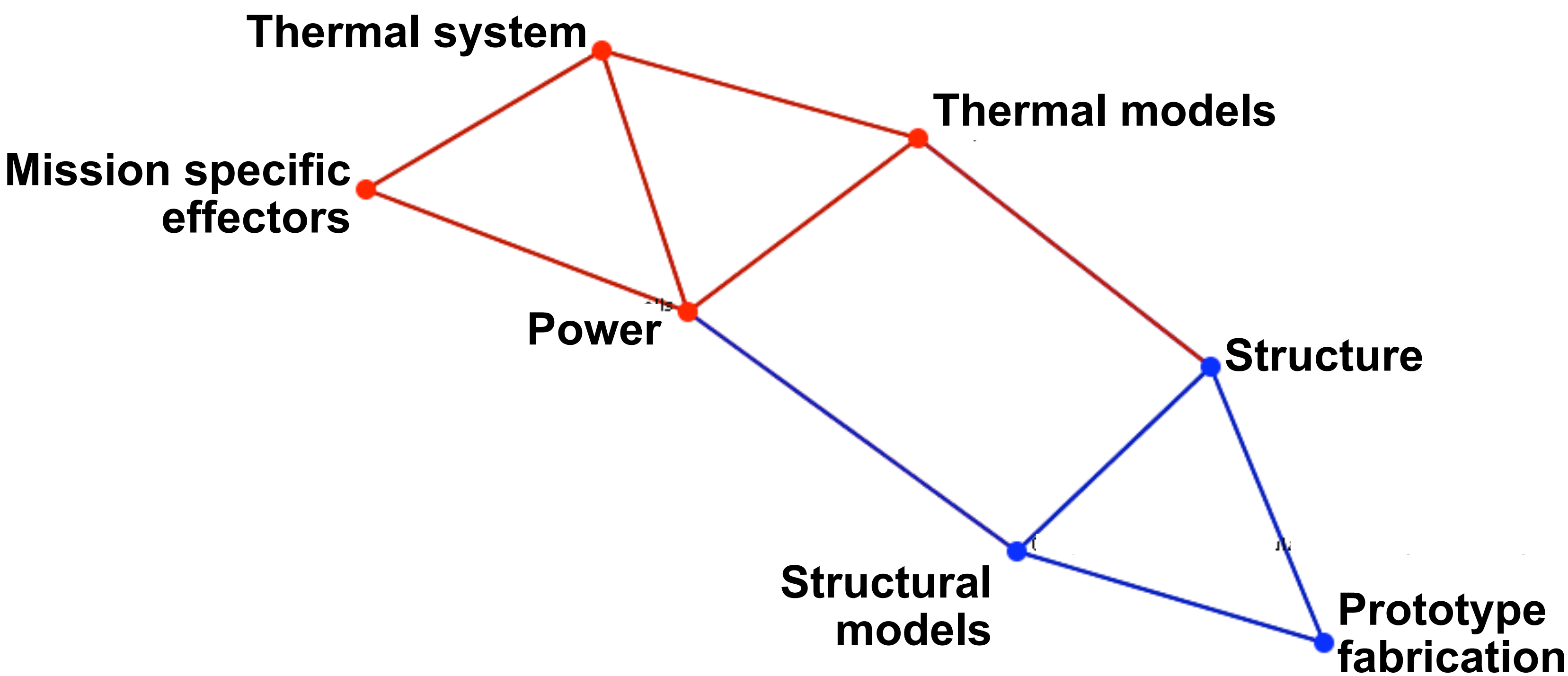
Thermal



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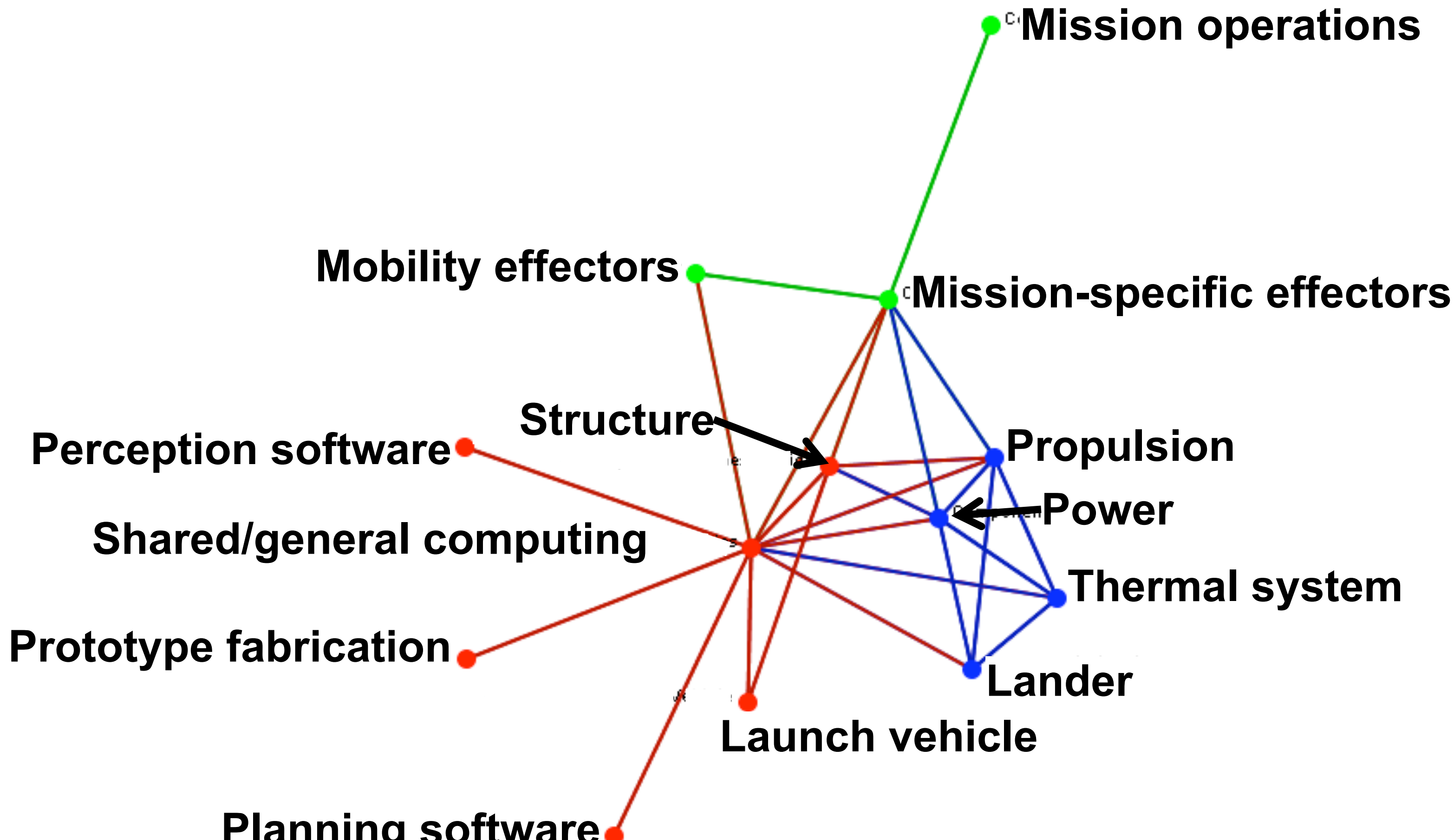
Avionics



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Concluding Vision

- The gray area – work that cross-cuts language constructs – is here to stay
- Use organizational tactics
- Use computations over artifacts generated by development activities
- Explore new data sources, including documents and conversation
    - Activities reveal knowledge
    - Analysis can often make it actionable

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