Studying Big Physics Experiments

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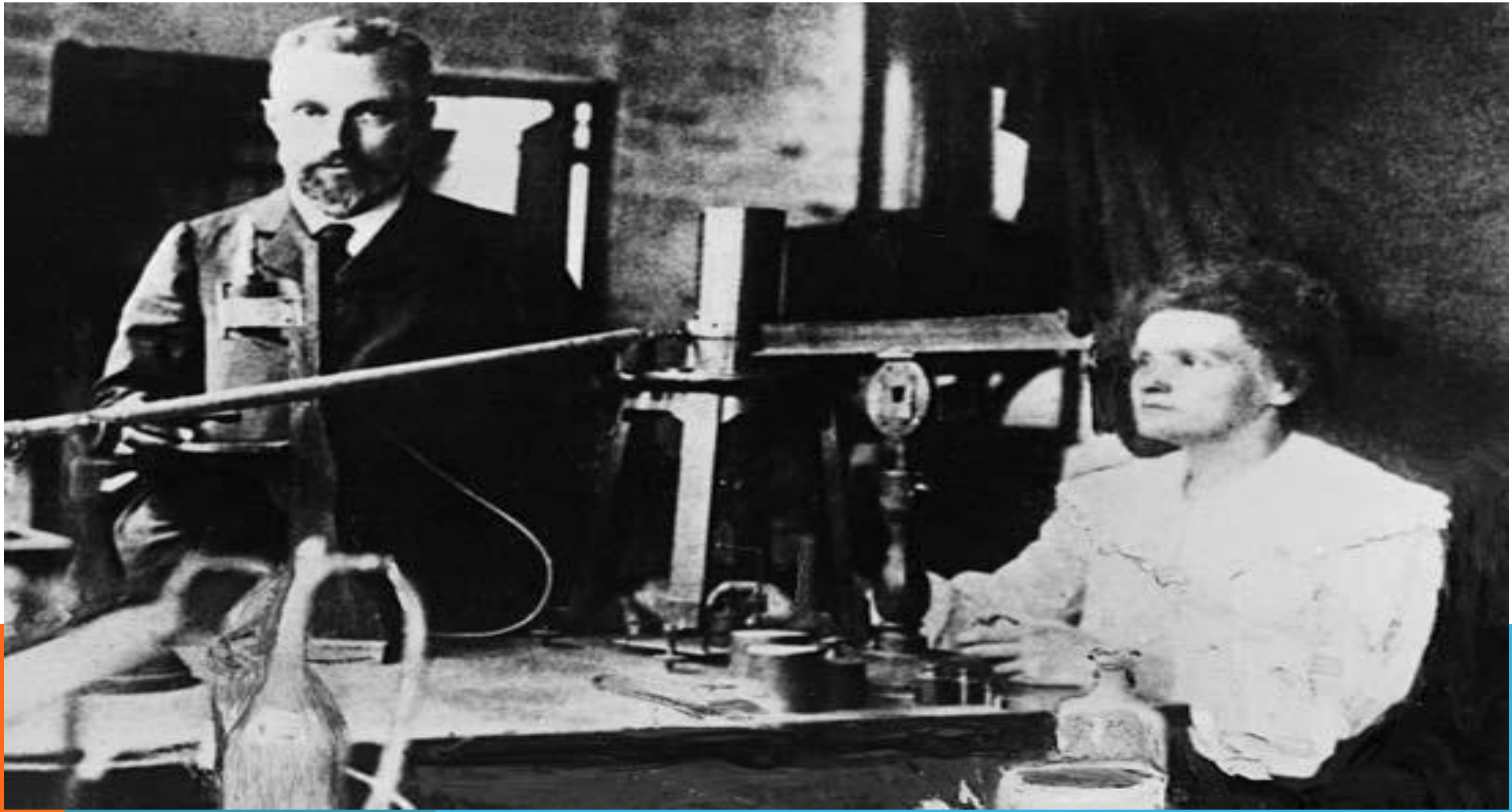
Is organizing experimental particle physics into mega-labs necessary and efficient?

Why is it organized that way? (Science, politics of funding, both?)

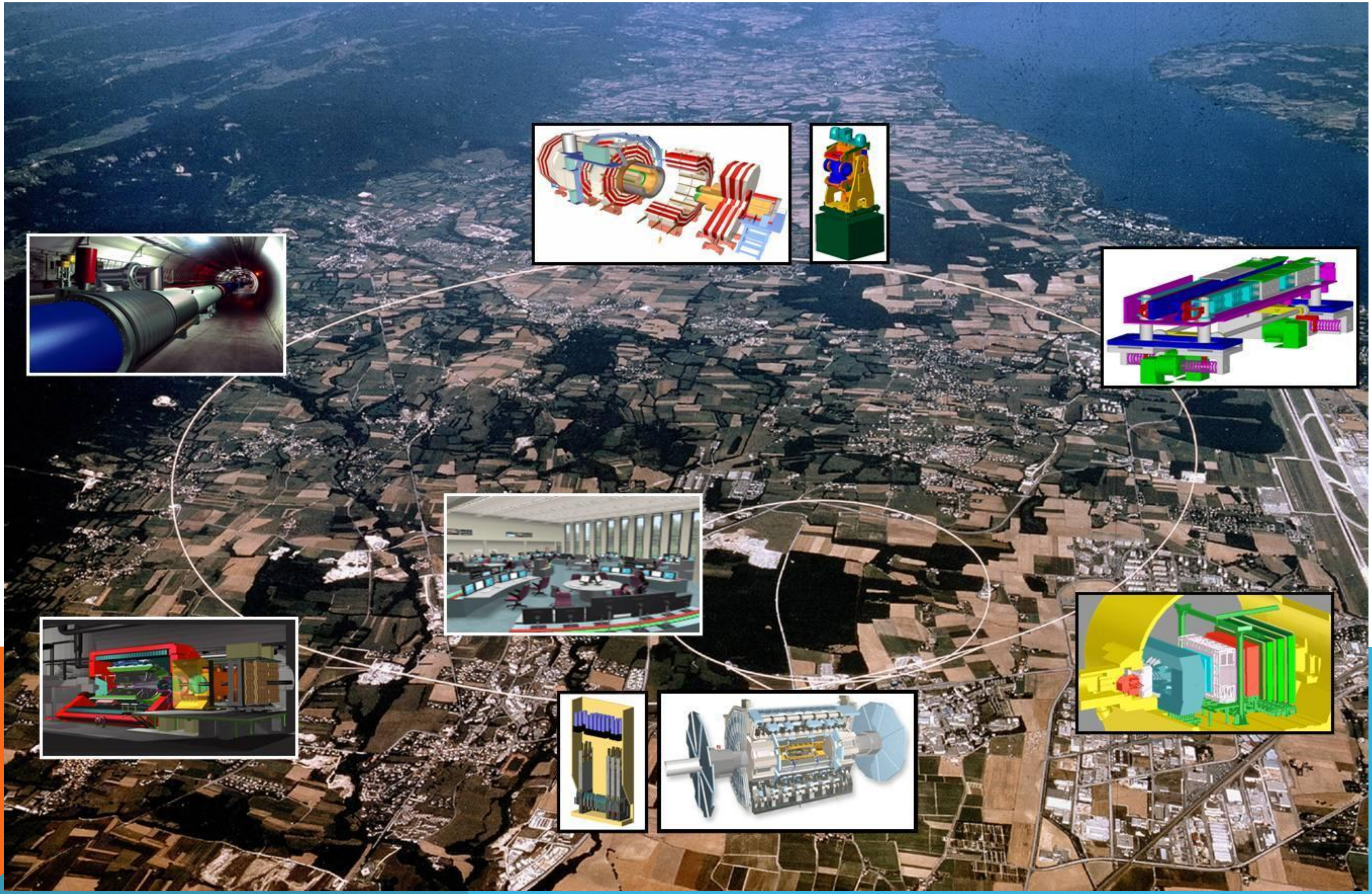
Can it be more efficient?

I. Organizing scientific research in epistemically efficient ways
II. Quantitative study of the team structure in HEP (Fermilab)
III. Is epist. efficient organization feasible?
IV. What can history tell us?
V. Inductive and operation analysis

I ORGANIZING LAB RESEARCH

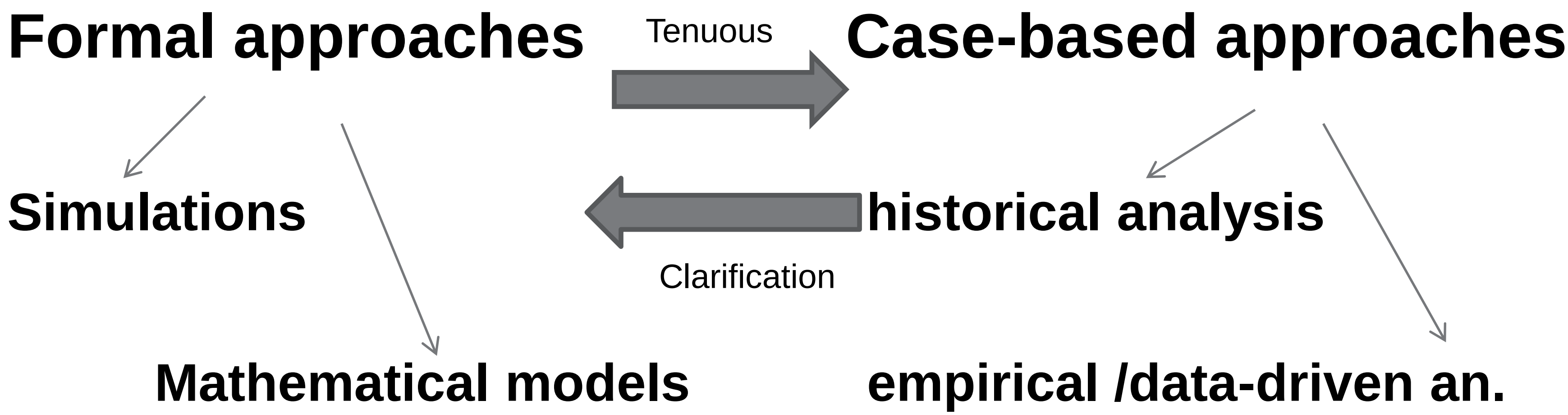


LARGE HADRON COLLIDER (CERN)



External forces (political, structure of funding, tradition, institutional inertia) shape the composition of research teams and labs

Are there optimal ways of organizing scientific teams and projects?


Formal approaches
Tenuous
Case-based approaches
Simulations
historical analysis
Clarification
Mathematical models
empirical /data-driven an.

Quantitative composition: Division of cognitive labor

1.Team composition: the number of researchers

2. Project (master-team) composition: number of teams

3.Composition of exploration: number and size of labs

"The researchers intuitively know how to divide into groups."

How do researchers divide into groups and why?

How they do it under pressure of time and limited funding, limited knowledge of what groups are going to do exactly?

Large labs

Are there generic rules of dividing them up that can avoid suboptimal ways of organizing them?

Too small - *a lack of diversity of viewpoints*

Too large

- cumbersome and prevent effective communication
- motivational issues

Too long – loose critical edge

Research in big pharma

Corporations (banks, financial industry, traders…)

Research policy studies: across sciences

Qualitative aspect of the composition: diversity (background knowledge)

"Diversity … can increase the bottom line by introducing more perspectives, heuristics, interpretations, and predictive models. … solve problems and make accurate predictions."

S. Page, 2007

K. Zollman: graph simulations

- connectivity
- shape of research network

S. Page: game theory approach

- The diminishing returns diversity theorem

A. Pentland: experiments with the markets

II FERMILAB – A QUANTITATIVE STUDY

Optimal research team composition: data envelopment analysis of Fermilab experiments

Slobodan Perović, Sandro Radovanović, Vlasta Sikimić & Andrea Berber

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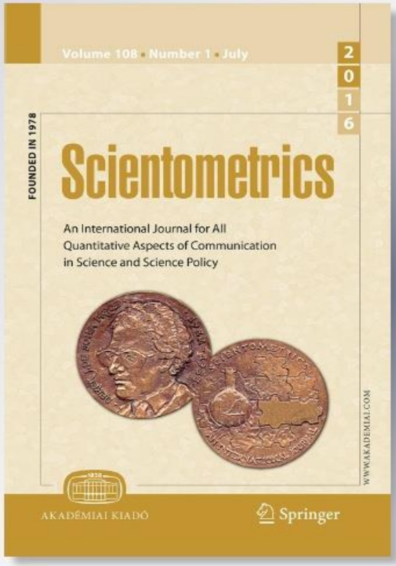

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- ***Data Envelopment Analysis* (DEA) - comparative efficiency with reference to the set of units that are compared with each other (rather than with reference to some external measure).**

  - The efficiency score: 0 and 100% (in case of an input-oriented model)

Data: 27 experiments from 1981 to 1995

Discovery experiments

New experimental techniques

Applications in other areas of physics

Left out:

- Calibration experiments
- Precision measurements
- Strings of experiments

- **Inputs:**
    1. the number of researchers within a project
    2. the number of teams within a project
    3. the duration of the project expressed in hours

- **Outputs: The weighted citations (9 categories)**

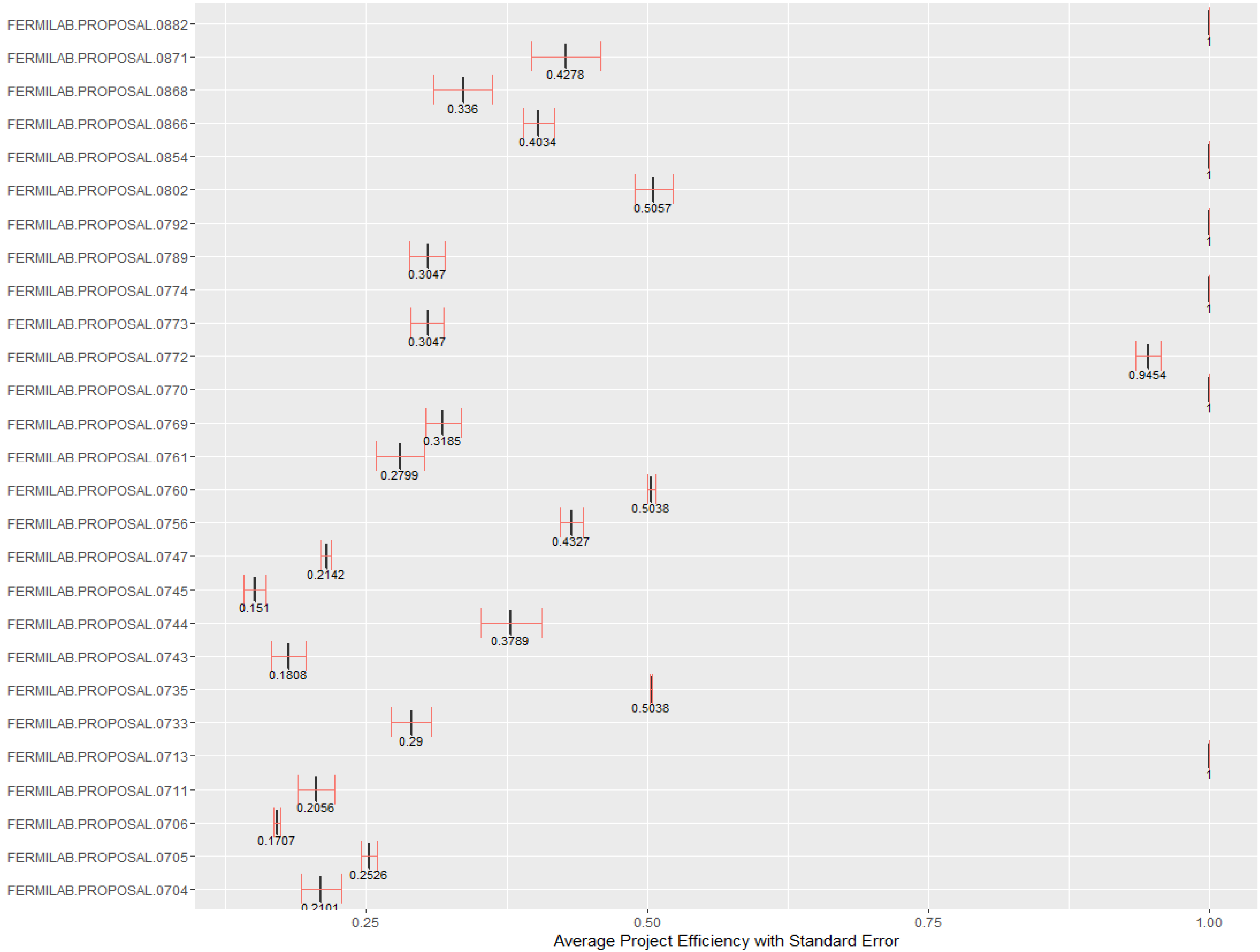
    - Quick convergence
    - Unique (or almost unique) experiments

    - Is it completed?
    - How fruitful has it been? (typically, motivated other experiments)

    - A qualitative check

Results:

- ***All six efficient experiments were very small (one or two small teams)***
- ***The inefficient experiments are all very large (several dozen/several teams)***



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1
0.2056
0.1707
0.2526
0.2101
0.25
0.50
0.75
1.00
Average Project Efficiency with Standard Error

Other factors:

The difference in seniority levels

In-house and outside teams

The mutual adjustment - negative atmospheric effects

Very efficient cross-expertise in small teams

The flat structure of communication – no hierarchy; creativity (Heinze et al. 2009, 617)

A number of smaller teams may be better at picking their research goals

History

- Initial organizational strategy at Fermilab - a sight for many smaller independent experiments
- Big colliders: a few long-running experiments

III HEP: BIG GOALS, HIGH ENERGIES, BIG EXPERIMENTS

The strategy that works: Break up into small-teams projects and diversify early

The Fermilab experiments? Restructure equipment, teams, tasks, and priorities

Are big labs simply collections of small labs (that evolve)?

Not really. 1) Specialized groups of a master-task. 2) Severe top-down constraints of the master-experiment.

Strategies of change of experimental Mega HEP:

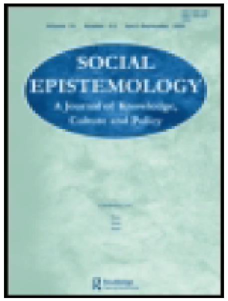
1. Different theoretical preferences

2. Actual smaller experiments that theory allows

3. The portfolio strategy (the CCD effect)

- Focus -> diminishing returns
- Spread -> a major technical problem becomes minor if resources are spread
  - E.g. development of linear colliders

IV HISTORY



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Egalitarian Paradise or Factory Drudgery? Organizing Knowledge Production in High Energy Physics (HEP) Laboratories

Slobodan Perović

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Manhattan project - Los Alamos lab

L. Alvarez, R.R. Wilson, L. Lederman, A. Weinberg and others, who were closely involved in it

“[i]t would be perhaps easier to list those [physicists] who did not [work in the project], for it included most of the Western world’s most brilliant physicists from legendary figures like Bohr to young and up-and-coming physicists like Richard Feynman” (Kragh 2002, 268)

HEP labs in the intersection of academia, state agencies, and industry.

Exponentially ever-larger and more complex knowledge-intensive operations, the laboratories have faced the challenges of, and required organizational solutions similar to, those identified by a cluster

Direct influence and hybrid developments (since Los Alamos)

Organization Theory

A cluster of theories that emerged out of industrial practice and academic and professional management studies of organization of industry and state administration.

1. Classical Organization Theory
   A sociological strand of Classical Modern Theory (that started with Weber)
2. Cultural Modern Theory
3. Rational Modern Theory
4. Structural Contingency Theory

Classical Organization Theory

- The organizational hierarchy, strict division of tasks, and specialization promoted by classical Organization
- Classical Organization Theory argues for long-term stable production as the goal of an organization.

- *Industrialization of knowledge production in HEP*
- Theory as the foundation of efficient industrial production emerged early in the development of HEP laboratories.
- With the increase in size of the laboratories, the initial short-term epistemic goals of testing specific hypotheses (hypotheses-confirmatory goals) steadily became only a part of the longer-term, broader epistemic goals of continuous wide knowledge production (long-term, optimally timed testing of a cluster of hypotheses, education of wider public, granting degrees, developing new technologies, etc.).

Sociological stream in classical Organization Theory

Administering and bureaucratizing knowledge production in HEP laboratories

The formal organizational structure tends to loosen up because of the fairly dynamic and unpredictable nature of the tasks and the focused expertise of most employees that cannot be supervised directly as supervisors lack detailed knowledge of the process (Von Nordenflycht 2010, Ditillo 2004, Karreman and Alvesson 2004).

The loosening of the organizational and managerial structure in such contexts may not be avoidable and may result in decreased efficiency (Alvesson and Svenigsson 2003).

This trend is certainly not a unique feature of HEP laboratories.

“Essentially, if an organization is to use complex machinery, it must hire staff experts who can understand that machinery - who have the capability to design, select, and modify it. And then it must give them considerable power to make decisions concerning that machinery, and encourage them to use the liaison devices to ensure mutual adjustment among them.” (Mintzberg 1989, 338)

“The enormous size of Big Science projects requires constant oversight by administrative bodies…. The true risk is excessive bureaucratization of large scientific projects. Public authorities, which have the fair duty of monitoring the expenses incurred by large projects, can impose decisions based on purely financial considerations, neglecting their scientific and technical aspects. Administrators are accustomed to operate quite different than scientists, and can even inadvertently destroy the special vitality that thrives in a research environment.” (Guidice 2012)

Cultural modern Organization Theory; informal and decentralized organization in HEP

- The anti-industrial reaction to the premises of classical modern Organization Theory that identified and promoted a focus on informal and flat organizational structures as the essential features of institutions
- Echoed in deliberate decentralization and matching open exploratory (as opposed to centralized confirmatory) epistemic goals in early phases of Fermilab and some other HEP laboratories.

Rational modern Organization Theory; formal streamlining of knowledge production processes in HEP

- Operational research approach that emerged with the Manhattan project promoted formally-based assessment and optimal operation of organizational structures
- Either overtly or covertly, this has been a steady feature of the development and operation of HEP laboratories.

Structural contingency Organization Theory; the size matters in organizing HEP

The organizational dynamics engendered by the size of laboratories – i.e. bureaucratization and hierarchy resulting from the increased size – is the key contingency in HEP laboratories in the optimization knowledge production.

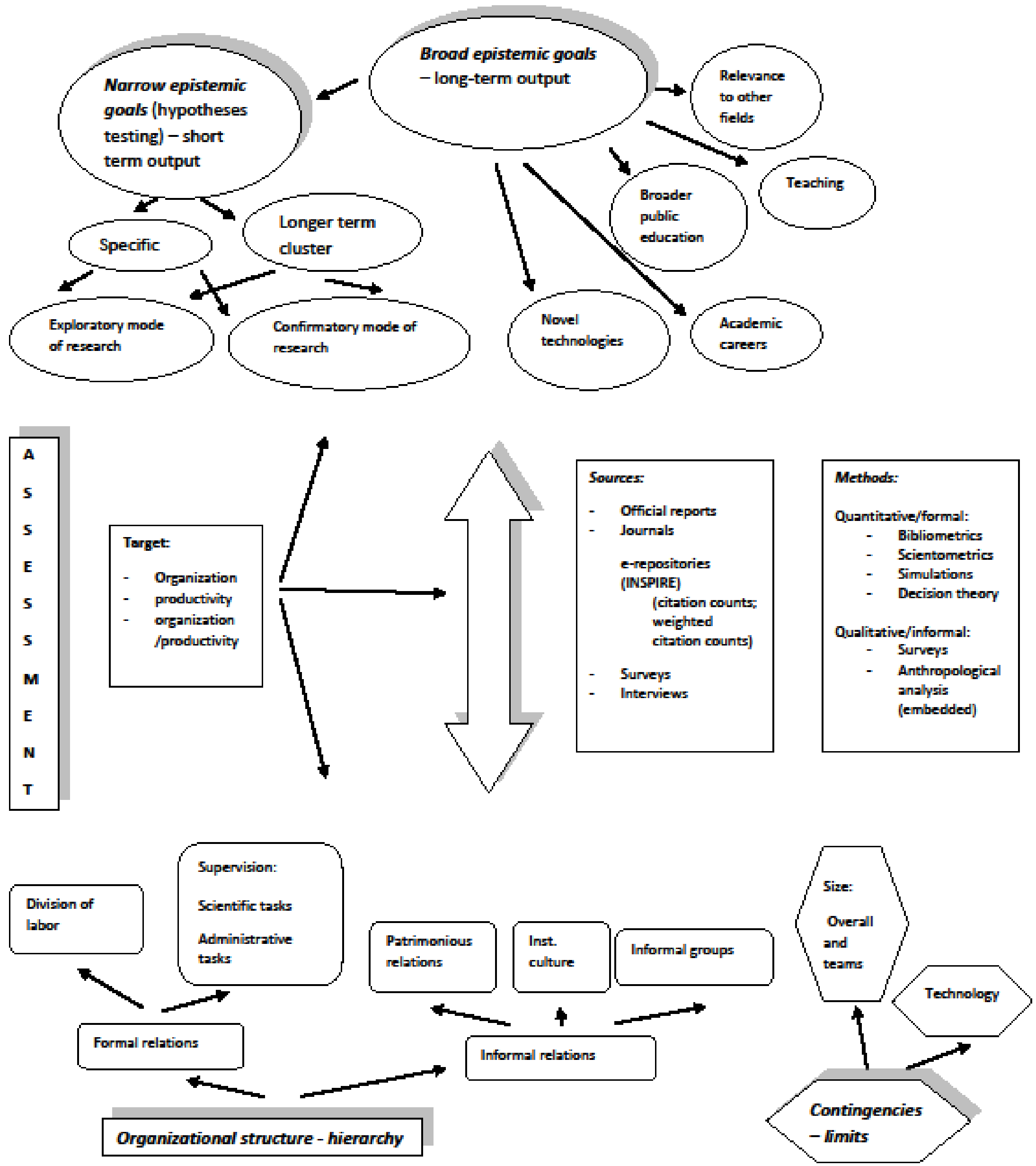
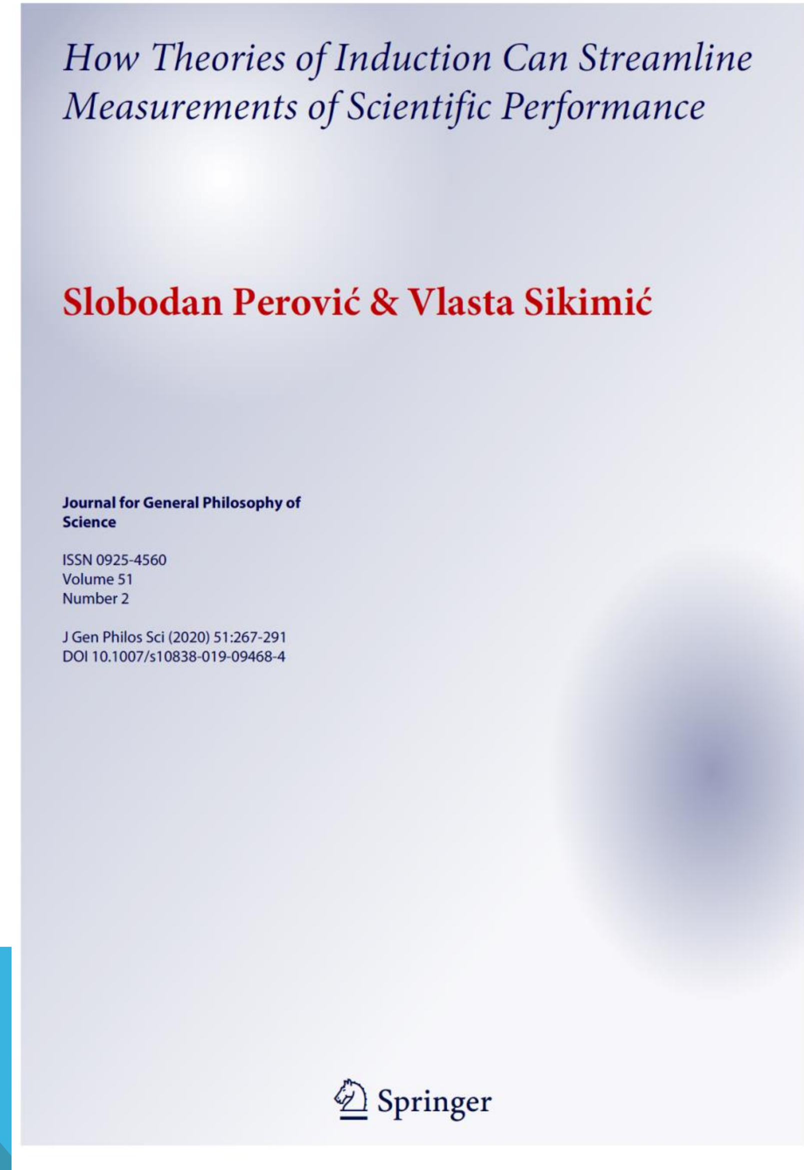


Diagram 1: The basic elements of the organization and epistemic goals of HEP laboratories, and the tools for assessing them and their relationship.

V INDUCTIVE AND OPERATIONAL ANALYSIS



How Theories of Induction Can Streamline Measurements of Scientific Performance

Slobodan Perović & Vlasta Sikimić

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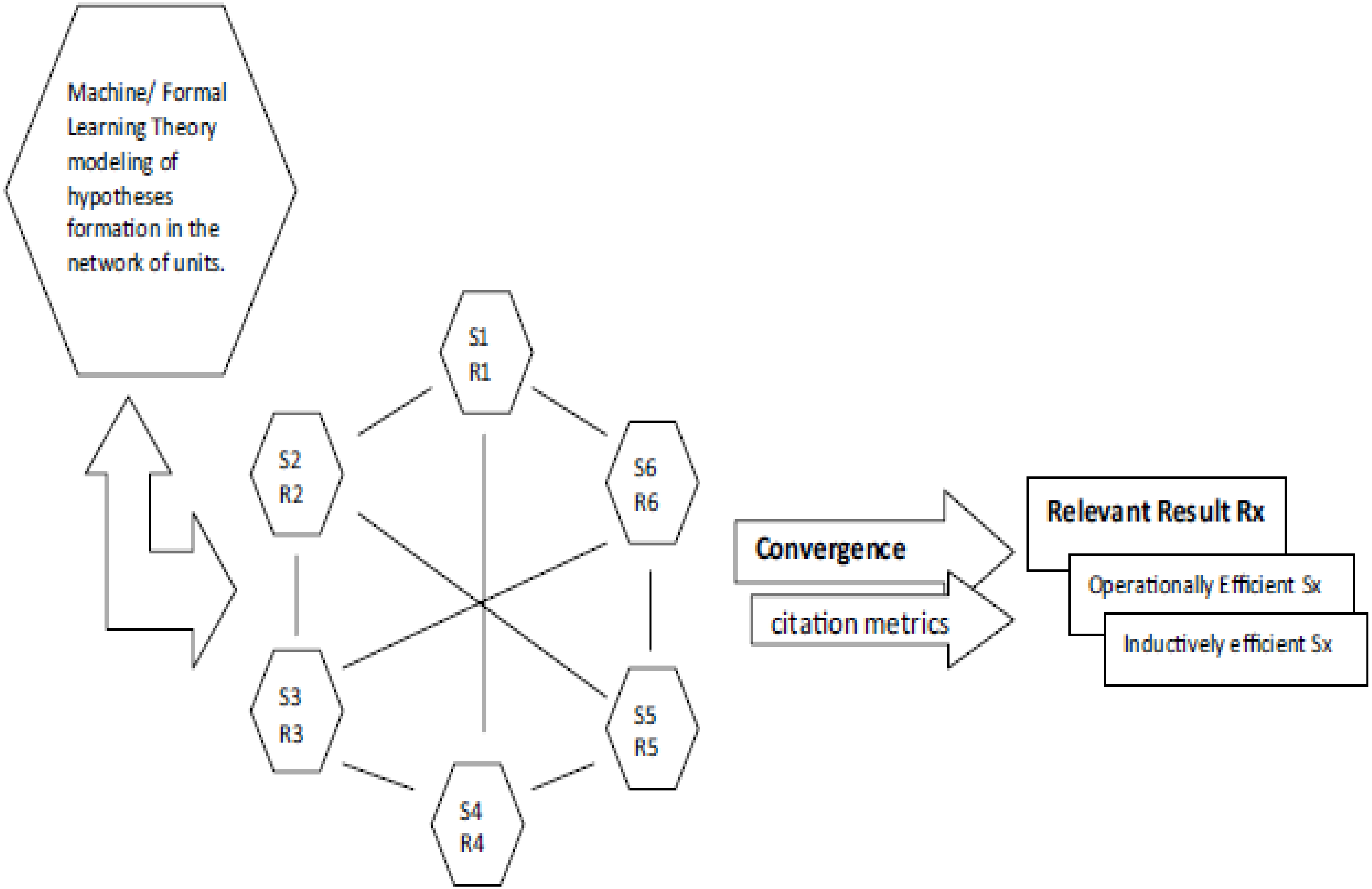
- Suitable theory of induction: Formal Theory of Learning
- Induction of hypotheses from a set of experimental data via a base-line principle (e.g. conservation laws in particle physics)
- Machine learning: early application inducing patterns in particle collider experiments

- A very homogenous experiments and a streamlined inductive process enable the application of inductive analysis and operational (e.g. bibliometric) analysis


Machine/ Formal Learning Theory modeling of hypotheses formation in the network of units.
S1
R1
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R2
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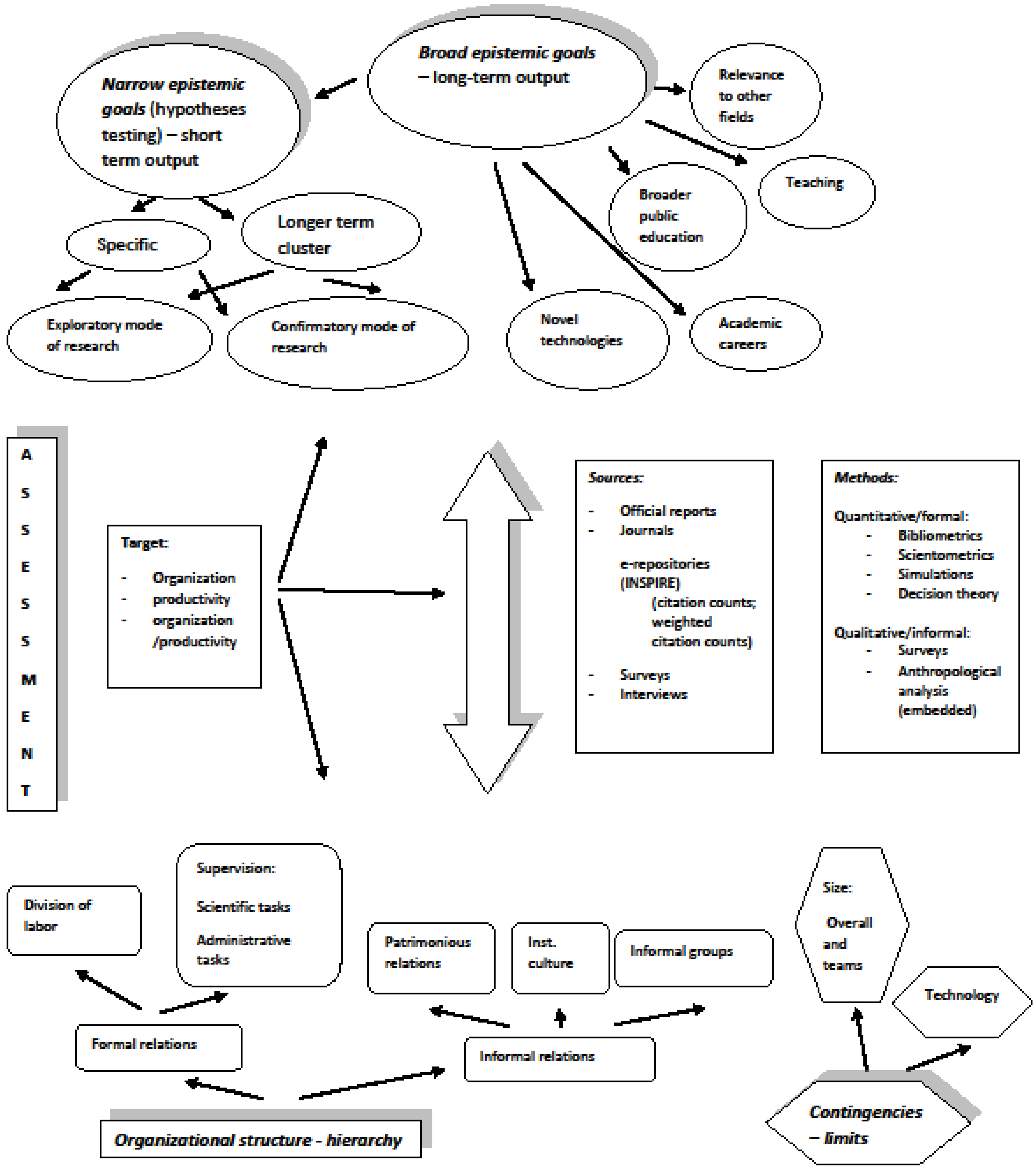
Convergence
citation metrics
Relevant Result Rx
Operationally Efficient Sx
Inductively efficient Sx



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