STATISTICAL ENGINEERING:
AN IDEA WHOSE TIME HAS COME

International Statistical Engineering Association

V.3, March 2021

STATISTICAL ENGINEERING
OUTLINE

1. Our conjecture
2. Michael I. Jordan viewpoint
3. *Why* statistical engineering?
4. *What* is statistical engineering?
5. *How* does statistical engineering work?
6. The International Statistical Engineering Association (ISEA)
7. Discussion

STATISTICAL ENGINEERING
CONJECTURE

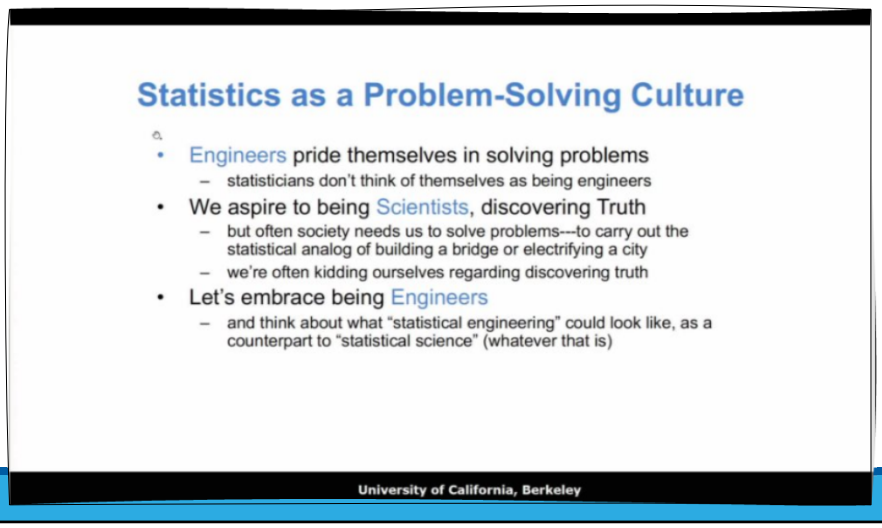
Our conjecture

- The development of the *theory and application of individual statistical and analytical methods* has gotten the profession far. However, we feel that "a lot of money has been left on the table," in terms of missed opportunities for greater impact on society.
- These lost opportunities relate to the need to think more deeply about how to capture major opportunities by *linking and integrating methods into an overall data-based approach to scientific inquiry*.

Effective data-based scientific inquiry involves more than a set of tools.

STATISTICAL ENGINEERING
MICHAEL I. JORDAN VIEW

Presented at the Symposium on Statistics in the Data Science Era
University of Michigan, 9/20/2019



Professor Jordan has a joint appointment with the statistics and computer science/EE departments at UC Berkeley. He is recognized globally as an authority on statistics, machine learning, and AI. In 2016, the journal *Science* named him the world's most influential computer scientist.

So, is this just a crazy idea, or is Jordan perhaps on to something critically important to the future of our profession?

STATISTICAL ENGINEERING
WHY?

- Michael I. Jordan (Berkeley):
  - "…society needs us to solve problems—to carry out the statistical analogue of building a bridge or electrifying a city."
  - "We're often kidding ourselves regarding discovering truth."
- Xiao Li Meng (Harvard):
  - Developed new course that "…emphasizes deep, broad, and creative statistical thinking instead of technical problems that correspond to a recognizable textbook chapter."
- Susan Hockfield (Former President of MIT):
  - Science develops the fundamental "parts list" (periodic table, human genome, etc.)
  - Engineering figures out how to "build something" of value to society from the parts list

Leaders in the profession have realized that something is missing.

STATISTICAL ENGINEERING
WHY?

ASA Guidelines for Undergraduate Statistics Programs:

- Undergraduates need practice using all steps of the scientific method to tackle real research questions. All too often, undergraduate statistics majors are handed a "canned" dataset and told to analyze it using the methods currently being studied. This approach may leave them *unable to solve more complex problems out of context, especially those involving large, unstructured data …. Students need practice developing a unified approach to statistical analysis and integrating multiple methods in an iterative manner.*

Emphasis ours

Teaching the ability to sequentially integrate tools is a widely recognized need, but largely unmet.

STATISTICAL ENGINEERING
WHAT?

International Statistical Engineering Association (ISEA) Definition:

- The discipline of statistical engineering is: the study of the systematic integration of statistical concepts, methods, and tools, often with other relevant disciplines, to solve important problems sustainably.

Key phrases and words:

- Discipline ("the study of") – not a collection of tools
- Integration – involves multiple methods/disciplines
- Other relevant disciplines – not limited to statistics or engineering
- Solve important problems – pro*blem or opportunity oriented* versus *tool oriented*
  - Statistical engineering is "tool agnostic"
- Sustainably – long term success is key

The engineering component to complement the science component.

STATISTICAL ENGINEERING
WHAT?

An observation:

- Scientists, engineers, and statisticians have been "building something" useful from the statistical science "parts list of tools" for a long time, to address large, complex, unstructured problems. However,
  - This was typically done in an "ad-hoc" manner, with little or no underlying theory documented to provide guidance to others.
  - Applications were typically "one-offs," requiring the "wheel to be reinvented" with each new problem.
- This approach of one-offs and ad-hoc approaches may work for a given problem, but is not how an engineering discipline develops.

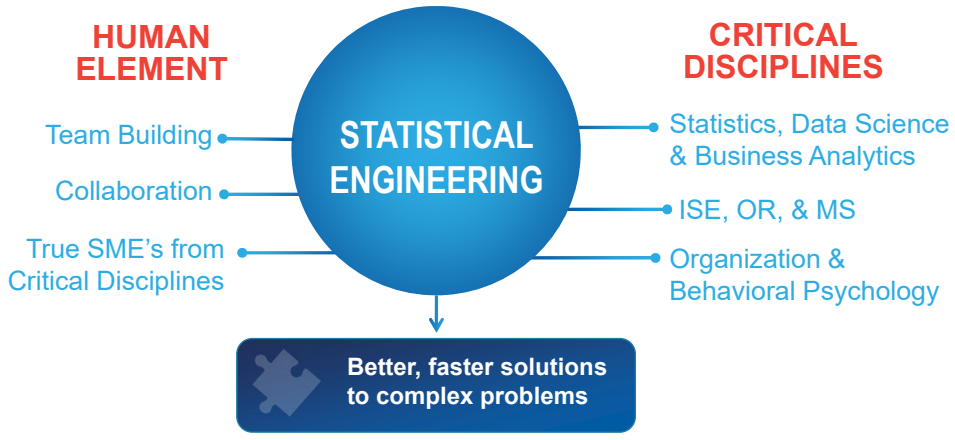
Statistical engineering is a new discipline, built on work of statistical pioneers.

STATISTICAL ENGINEERING
WHAT?

Is:	Is Not:
Engineering solutions to large, complex, unstructured (LCU) problems	*Applied statistics*
A holistic approach	A purely *technical* approach
Tool *agnostic*	A *recommended set of tools*
Based on the *scientific method*	Based on *algorithms & number crunching*
Viewing data as a *means to an end;* i.e., data are a *"how"*	Viewing data as *an end in themselves;* i.e., data are the *"what"*
Neutral and broad in application area	*Engineering statistics*

Statistical Engineering offers the potential for a dramatic increase in impact.

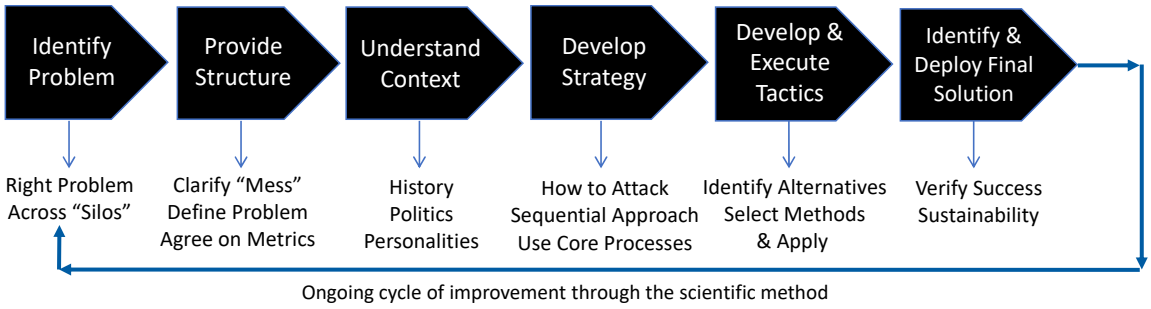
THE INTEGRATIVE ROLE OF STATISTICAL ENGINEERING



Note: SMEs – subject matter experts; ISE – Industrial and Systems Engineering; OR – Operations Research; MS – Management Science

STATISTICAL ENGINEERING
HOW?

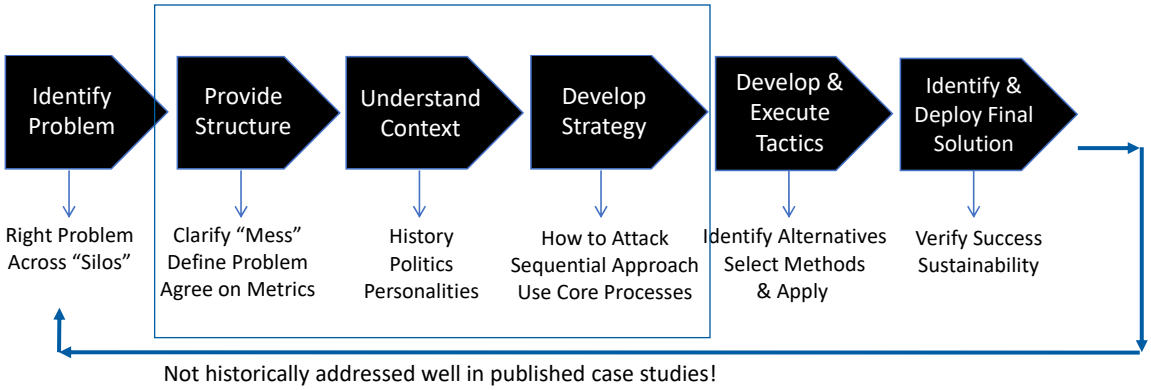
The Typical Phases of Statistical Engineering Projects



A "unified approach to statistical analysis and integrating multiple methods…"

STATISTICAL ENGINEERING
HOW?

The Typical Phases of Statistical Engineering Projects



A "unified approach to statistical analysis and integrating multiple methods…"

STATISTICAL ENGINEERING
HOW?

Key principles of statistical engineering:

1. Understanding of the *problem context* as a key preliminary step
2. Development of an overall *problem-solving strategy* to drive a sustainable solution
3. Documentation and consideration of the *data pedigree*, prior to conducting any data analysis
4. Careful integration of *subject-matter knowledge* with data analysis
5. Utilization of *sequential approaches*

These are not always needed for textbook problems,
but are needed for engineering solutions to complex problems.

STATISTICAL ENGINEERING
HOW?

Core processes of statistical engineering

The *strategies* developed to succeed with complex problems and opportunities (Phase 4) typically involve some mix of the following high-level statistical processes:

1. Data collection – acquisition of the *right data*
2. Data exploration – *generating hypotheses*, in conjunction with subject matter knowledge
3. Model building – of *various types*, and from *various disciplines*
4. Drawing inferences – *testing hypotheses*, and developing appropriate conclusions *beyond this data set*, again in conjunction with subject matter knowledge
5. Solution identification and deployment – making statistical analyses *actionable and sustainable*

These must be integrated with sound organization effectiveness principles to succeed.

STATISTICAL ENGINEERING
ISEA

- ISEA legally incorporated in 2018
- Over 300 members as of today
  - Individual membership is free
- Holds annual Statistical Engineering Summit
  - Providing webinars for 2021 Summit
- Now sponsoring Stu Hunter Research Conference
- Writing Statistical Engineering Handbook
  - Handbooks are typical for engineering disciplines
  - Available to members on ISEA website (isea-change.org)

From incorporation to 300 members in just over two years.

STATISTICAL ENGINEERING
SUMMARY

- Our core message is that the statistics/analytics profession has the potential to significantly enhance its impact on society
- Along these lines, Michael Jordan pointed out the need for an engineering mindset to balance a statistical/data science mindset
- Integration of multiple methods to solve large, complex, unstructured problems is a unique, and to a large degree, unmet niche
- ISEA has taken some specific steps to make this address this oversight
- The Statistical Engineering Handbook is nearly finished
  - Most chapters are complete and are available to members on ISEA website
- Lots of work remains, including further development of the underlying theory of statistical engineering

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DISCUSSION

