

REIMAGINING SCIENCE AND ENGINEERING INDICATORS

About Science and Engineering Indicators

Science and Engineering Indicators (*Indicators*; “main report”) is the National Science Board’s flagship report on indicators of the state of the U.S. science and engineering enterprise. It is produced by NSF’s National Center for Science and Engineering Statistics (NCSES) on behalf of the Board and transmitted to Congress and the President on or before January 15 of even-numbered years in fulfillment of statute.

The report covers U.S. and international data on all levels of STEM education, the STEM workforce, R&D investment, knowledge and technology industries (e.g., high-tech manufacturing), innovation, public attitudes towards and knowledge of science and technology, and S&E-related state indicators. The report uses a combination of graphics and explanatory text, organized in thematic chapters, to convey information. For the 2016 edition, the state data chapter was converted to a standalone online ***State Data Tool***.

The “**Overview of the State of the U.S. S&E Enterprise in a Global Context**” (Overview) is a critical section of the main report. It is the section of *Indicators* that comes closest to answering the question, “What is the state of S&E in the United States?” It brings together key S&E indicators selected by the NSB and typically places them in an international context. It contains a mix of narrative text and graphics, and it is policy neutral.

The ***Indicators “Digest”*** is a condensed version of *Indicators* comprising a small selection of important themes and related data. Although it is not part of the main *Indicators* report (and thus not technically part of fulfilling the statutory mandate), it is produced and published simultaneously with the main report. The *Digest* serves two purposes: (1) to draw attention to important trends and data points from across the chapters of *Indicators* and (2) to introduce readers to the data resources available in the main volume of *Indicators* and associated products. The *Digest* is aimed at all varieties of users who prefer to learn about key indicators “at a glance.”

Strategic Considerations in Developing Indicators and the Digest

The *Indicators* main report (thematic chapters, *Overview*, and *State Data Tool*) and the *Digest* are policy neutral.¹ This means they do not contain recommendations or offer opinions about the policy implications of the data. They also don’t employ statistical models to draw conclusions (e.g., modeling STEM workforce supply and demand). With one exception,² *Indicators* does not contain projections; it is exclusively retrospective in its coverage.

Indicators and the *Digest* aim to be policy relevant. This means the Board and NCSES must consider the current (and emerging) S&E policy context so that the data included in these resources are relevant and timely to Congress, the President, and other stakeholders. Our aim is to understand the questions that policy makers are asking (or should ask) and provide data and analysis that help inform their answers—and to do so in a way that is credible, balanced, accessible, and comprehensible.

¹ The NSB made the decision at the inception of *Indicators* that the report would be policy neutral. There were others in the Federal Government who preferred that the Board take a non-neutral approach. In this letter, the Board explained its rationale: <https://1drv.ms/b/s!AtICFjIh753gP9icY0Dx5Wwy4ILRug>

² BLS occupational projections in Chapter 3.

There are additional important strategic considerations for the Overview and *Digest*. Both resources present a subset of the data and analysis in the main report. Therefore, NCSES and NSB must choose which indicators within the main report are most important/relevant to highlight in each product. Similarly, because the Overview uses a narrative structure (i.e., it tells a story), consideration is also given to how to frame the information in the Overview. If the publications highlighted only indicators that showed that the United States was “falling behind,” was “winning” on all fronts, or framed the narrative as solely in terms of global competition rather than a mix of competition and cooperation, users could reasonably accuse the NSB of “cherry-picking.”

Policy companions offer the NSB a platform for offering recommendations to stakeholders, discussing the policy implications of the data, considering using statistical models to draw inferences, and offering informed opinions on emerging trends. Policy companions take many forms—from 1-2-page statements to 20+ page reports (in both print and digital formats). They always draw on the data and analysis within *Indicators*. At times, companions have also contained new analyses of existing *Indicators* or NCSES data and/or have drawn on other information from credible non-*Indicators* sources. Although there’s no statutory requirement to produce a policy companion to *Indicators*, the Board has published at least one companion every two years with few exceptions.

Fulfilment of Statute and Production

Fulfilment of Statute: The relevant section of the NSF Act reads:

*The Board shall render to the President and the Congress no later than January 15 of each even numbered year, a report on indicators of the state of science and engineering in the United States.*³

Importantly, the law leaves much to the NSB’s discretion. For example, it does not specify the size of the report, the format (print or digital), how often the data and analysis are updated, or even that the report must be policy neutral (this was a decision made by the NSB in the 1970s).

The *Indicators* main report is the way the NSB has chosen to meet its statutory obligation.

Indicators Production: The entire production and review process for *Indicators* and the *Digest* is built around the goal of delivering *all* the content in both products simultaneously by the statutory deadline. (The policy companions are produced and published on a separate schedule.)

Tradeoffs for Users; Challenges for NCSES

Production Tradeoffs: The NSB’s decisions regarding *what* to produce in fulfilment of statute and *how* to produce it create important tradeoffs for users, NCSES staff, and the Board itself.

Producing and delivering all the content within *Indicators* and the *Digest* simultaneously limits the timing (when data are published) and timeliness (the recency of the data). Currently, the report (eight chapters, *Overview, State Data Tool*) and *Digest* are produced and published concurrently on a rigid 2-year cycle. Production of the next edition of *Indicators* begins almost immediately after publication of the prior edition. This means that once published, the report and related resources remain essentially static (i.e., no updates or revisions) for two years until a completely new digital report takes its place.

³ [42 U.S. Code § 1863 \(j\) \(1\)](#)

December 7, 2017

Simultaneous production of the main report and Digest means that the deadline for incorporating updated or new data is roughly four months prior to January 15 of even-numbered years. This is important as the availability of new data often do not align with *Indicators* production deadlines. Thus, the information in *Indicators* and the Digest can become quickly outdated soon-after publication or, in some instances, even prior to publication.

Expansion of *Indicators*: Over time the report has grown considerably—from a 150-page print report in 1972 to a nearly 1500-page 2-volume print report in 2014. For the 2016 edition of *Indicators*, the NSB and NCSES transitioned the report from print to digital while keeping the amount of content and overall thematic chapter structure largely the same apart from the chapter on state indicators, which transitioned to an online state data tool.

Indicators has grown in size and complexity as a byproduct of the review process rather than due to a strategic decision by the Board or NCSES. For instance, staff asks the NSB and expert reviewers to identify gaps in the information. As the available data on S&T increases, so too does the size of *Indicators*. An equally robust mechanism has not been implemented to remove topics and data.

Challenges for Users: In addition to the lack of timely data, users frequently point to the size and complexity of the main report as a key challenge. During a recent *Indicators* user workshop (see [Workshop Summary](#)), attendees described the amount of information in the report as often overwhelming. This limits its usefulness, especially for users who are less experienced working with complex data and information.

The desire to make *Indicators* more user-friendly motivated the transition of the *Indicators* main report from print to digital. NSB and NCSES also have attempted to address the usability challenge by creating additional resources derived from the main report. The best example of this is the *Digest*, which originated in the early 2000s. In recent years, the Board has developed a variety of other ad hoc resources to augment *Indicators*. For instance, the NSB created an interactive infographic of the Overview in 2016 and a STEM education online tool and a mobile app in 2012 and 2014.

Challenges for NCSES Staff: NCSES is Federal statistical agency has numerous other responsibilities in addition to producing *Indicators*. The ever-increasing size of *Indicators*, the rigid, near continuous 2-year production cycle, and the decision to produce and deliver the entire main report and the Digest simultaneously puts enormous pressure on NCSES. Producing additional *Indicators*-related products (*Digest*, infographics, and other tools) only adds to this burden. In the past few years NCSES has lost key members of staff due, in part, to the stress and workload of *Indicators*, adding urgency to the importance of the redesign of *Indicators*.

Challenges for the NSB: The NSB's Committee on National S&E Policy (SEP) is charged with not only overseeing production of *Indicators*, but also helping the Board fulfil its mandate to provide Congress and the President with policy advice on S&E issues and promote and encourage policies to advance S&E in the United States. However, the vast majority of the Committee's time is devoted to overseeing production of *Indicators*. Committee members also have noted that the size and complexity of *Indicators* means that members review the report in parts; members are not realistically able to review the entirety of the report. A different, more manageable deliverable and flexible production schedule would enable the Committee to provide more comprehensive and strategic feedback.

Taking Advantage of Digital Capabilities to Improve Usefulness and Timeliness of Indicators

The transition of *Indicators* and the related resources to a digital format affords the NSB and NCSES the opportunity to (1) enhance the usability/accessibility of *Indicators*, the Digest, and other related resources; (2) improve the timing/timeliness of the data and information in these products; and (3) create flexibilities and efficiencies for staff and the NSB.

Usability/Accessibility: Users of *Indicators* are diverse both in who they are (e.g., policymakers at all levels, researchers, educators, the public) and how they use the data. During discussions with users, the NSB and staff learned that they value data that are easily accessible, interpretable, and offer flexibility in how they can be used. For example, some users prefer highlights and take-home messages, while other users prefer to customize the underlying data and perform their own analysis and interpretation.

Unlike print content, which is static with a predetermined presentation style, digital content is dynamic and can be presented differently to users with different needs and experience working with complicated information. Likewise, digital data and information can be dynamically assembled in real-time in a variety of different ways—by topic, by year, by country, by race/ethnicity, level of degree, etc.—rather than in a predetermined format (e.g., eight sequential thematic chapters). Digital content also makes it possible to automate at least some of the content assembly and visualization.

Taking full advantage of digital capabilities within the main report could lead to valuable improvements for casual and power users alike. Rather than the NSB and NCSES choosing a single presentation format that may or may not suit the needs of a given user or creating another supplementary resource (e.g., Digest), we could build an *Indicators* interface that would give users a choice in how to visualize the content.

Data Timeliness/Timing: The transition of *Indicators* from a print report to a digital report has created potential opportunities to be more flexible—not only flexibilities in how the content is displayed, but also when the content is published and updated. Prior to 2016, it simply was not practical to publish new or revised versions of the print report in between 2-year cycles.

Yet, we continue to treat *Indicators* as a report in that all the content is updated/revised simultaneously, it is published to the Web *en masse*, and remains static (i.e., canonical) until a new digital report takes its place. Because *Indicators* now exists digitally online, the data and analysis are always “live.” This means that any portion of the report theoretically can be changed without the need to create, layout, and publish an updated print report or create a new digital report every time the data and information are revised.

By adopting an approach to production that takes full advantage of digital flexibilities, the periodicity of *Indicators* updates could be harmonized with data availability schedules, resulting in a digital resource that contains the most timely data over an entire 2-year period. This could yield enormous benefits for users, particularly Administration and Congressional staff who require the most current data to help inform budgetary decision-making, assess the impact of S&E-related policies, and understand the relative standing of the U.S. S&E enterprise in a rapidly changing global environment.

This also could yield benefits for the NSB and staff as well, providing both with greater flexibility in managing resources. Content creation and publication could be spread out over time rather than creating/updating and publishing all *Indicators* and *Digest* content simultaneously. The Board and NCSES could determine collaboratively what data are updated when. NCSES would not necessarily need to create a new *Indicators* website every two years.

What's Required to Move Forward?

Fundamentally, the NSB would need to consider what it means to fulfil their statutory obligation in the “digital era.” The statute says that the NSB must deliver to Congress and the President “a report on indicators of the state of S&E in the United States every two years.” In the “print era” how to do this was relatively obvious—the NSB would create and publish a printed report of these indicators every two years. This report served as a canonical 2-year snapshot of the state of S&E. The process for producing, updating, and delivering content flowed naturally from this model.

But given advances in technology, including digital dissemination and consumption of online content, and the unsustainable growth of the report’s size, the Board should revisit how best to fulfil its statutory mandate in the near- and long-term. Taking advantage of digital capabilities to improve the usefulness and timeliness of *Indicators* and create flexibilities and efficiencies for NCSES staff (as described above) would necessarily decouple creation/revision of the data and analysis in *Indicators* from the statutory deadline. It would transform *Indicators* from a canonical reference report into an always-available, dynamic digital resource. The primary driver for *Indicators* and related products would shift from “produce, update, and deliver all content simultaneously by January 15” to “produce, update, and deliver content in a way that ensures the data and analysis are as timely and relevant as possible **and** is most efficient for staff.”

Thus, as a first step, the Committee on National S&E Policy and the full Board should articulate the principles and/or goals that should drive what the NSB and NCSES produce, how it is produced, and when and what is delivered in fulfillment of statute. Statute does not require the Board to produce and deliver the equivalent of 1500+ pages of data and text along with a state data tool and Digest. Importantly, any “rethinking” of *Indicators* must be anchored to the principle that the NSB will continue to meet its stature obligation and that *Indicators* will exceed user expectations for quality, usability, and timeliness.

With a clear articulation of the principles/goals that should drive *Indicators* in hand, there are numerous ways that the NSB and NCSES could take advantage of digital capabilities ranging from modest changes in what is produced and delivered in fulfilment of the law to a far more radical reimagining. Many of these changes would require a significant rethinking of *what* the NSB delivers to Congress and the President and *how* these resources are produced and published. Any alternative model would require the input of experts (e.g., data scientists) and key stakeholders (e.g., Congressional and Administration staff) to explore the tradeoffs between the current model and alternatives.

Reinventing *Indicators* will be a multicycle process, providing opportunities for testing and evaluating options. NCSES is looking for guidance from SEP as plans for *Indicators 2020* are being developed. For *Indicators 2020*, NCSES has about eight months to develop the plan that will be implemented for the next *Indicator* cycle.

The following two presentations were given by NCSES staff at the SEP retreat in order to provide the group with fuller context on the mission and activities of NCSES and considerations regarding *Indicators* report production



NCSES and S&E Indicators

Committee on National S&E Policy Retreat
January 31, 2018

John R. Gawalt
Director, NCSES

Emilda B. Rivers
Deputy Director, NCSES

*National Science Foundation
National Center for Science and Engineering Statistics
www.nsf.gov/statistics*



National Center for Science and Engineering Statistics

The National Center for Science and Engineering Statistics (NCSES) was established within the National Science Foundation organic Act to serve as a clearinghouse for information on the science and engineering enterprise.

We are responsible for statistical data and analysis on topics that include:

- Research and development
- The science and engineering workforce
- U.S. competitiveness in science, engineering, technology, and R&D
- The condition and progress of STEM education in the United States



An Organization within the Federal Statistical System

- NCSES is one of 13 Principal Statistical Agencies
- OMB's Office of Information and Regulatory Affairs coordinates the nation's decentralized federal statistical system
- US Chief Statistician promotes integration by chairing the Interagency Council on Statistical Policy (ICSP)
- As a member of ICSP, NCSES staff engage in a number of ICSP-led projects of mutual interest and benefit



Organizational Placement of NCSES

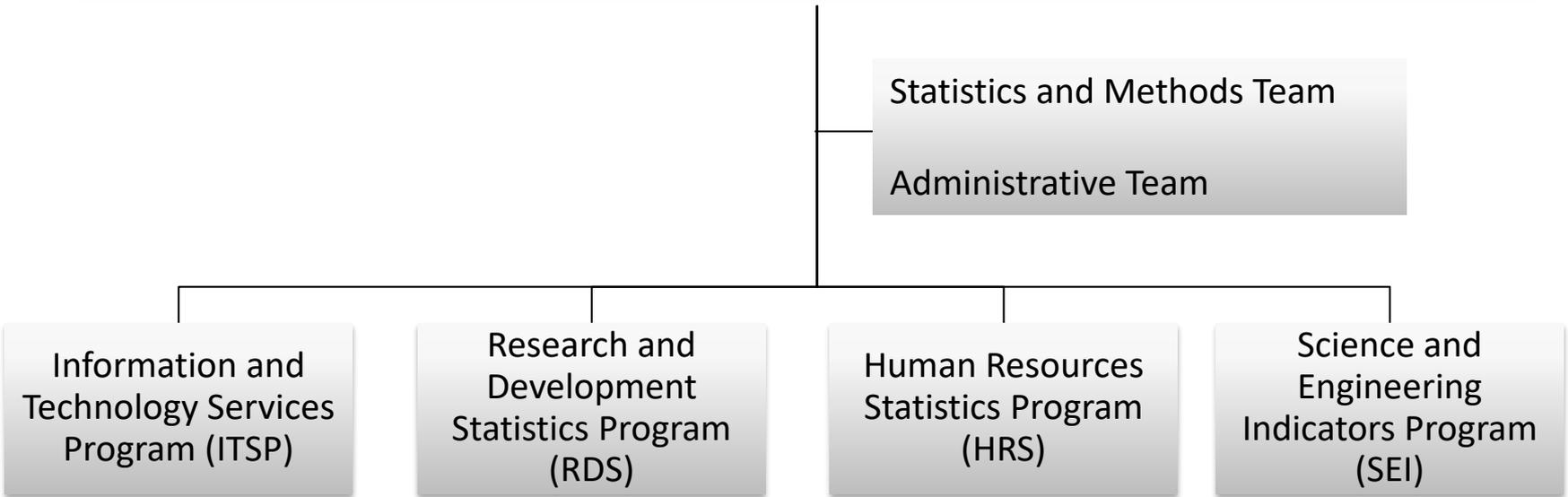
National Science Foundation

Directorate for Social, Behavioral and Economic
Sciences

National Center for Science and Engineering
Statistics



National Center for Science and Engineering Statistics



Staff and Contract Resources

NCSES has about 49 staff and an annual budget of \$50 million

- Survey managers
- Statisticians
- Analysts
- Publishing
- Web site and database development
- Administrative (budget, staffing, office operations)

Surveys are conducted under contract or interagency agreement, none are done in-house

Technical support for Web site and database development is provided by contract staff, some of whom work onsite



Core Activities

- Gather science and technology (S&T) -relevant data from other agencies and organizations
- Develop and maintain databases on R&D, S&E education, the S&E workforce, and related areas
- Provide global context for U.S. data and enable comparisons and benchmarking through national and international collaborations
- Prepare and publish periodic reports for a broad clientele



Research and Development Statistics Program (RDS)

- Business R&D and Innovation Survey (BRDIS)
- Micro-business R&D and Innovation Survey (M-BRDIS)
- Annual Business Survey (forthcoming)
- Higher Education R&D Survey (HERD)
- Survey of Federal Funds for R&D
- FFRDC (Federally Funded R&D Center) Research and Development Survey
- Survey of Federal S&E Support to Universities, Colleges, and Nonprofit Institutions
- Survey of State Government R&D
- Survey of Nonprofit Research Activities (forthcoming)
- Survey of S&E Research Facilities



Human Resources Statistics Program (HRS)

- Survey of Graduate Students and Postdoctorates in Science and Engineering (GSS)
- Survey of Postdocs at Federally Funded Research and Development Centers
- Survey of Earned Doctorates (SED)
- Early Career Doctorates Survey (ECDS)
- Survey of Doctorate Recipients (SDR)
- National Survey of College Graduates (NSCG)

Additional Ongoing Programmatic Activities

- Research on the Science and Technology Enterprise: Statistics and Surveys
- Contributor to the Science of Science and Innovation Policy (SciSIP), an NSF initiative which is developing the data, tools, and knowledge needed to develop a new science of science and innovation policy
- Federal R&D Reporting Standards – FTAC-RDRS
- Cooperative Agreement with Virginia Tech’s Social and Decision Analysis Laboratory
- OECD, National Experts on Science and Technology WG



Information and Technology Services Program (ITSP)

Online Databases:

- SESTAT (Scientists and Engineers Statistical Data System)
- WebCASPAR (Web Computer-Aided Science Policy Analysis and Research) database system
- IRIS (Industrial R&D Information System)
- Other data-driven applications
 - *Academic Institutional Profiles*
 - *State S&E Profiles*
 - *State Data Tool (S&E Indicators)*

Data files:

- Public Use Files
- Restricted Use Data Files (licensed datasets)

Publications and Products

- InfoBriefs
- Detailed statistical tables

InfoBrief

NCSES National Center for Science and Engineering Statistics

December 2017 ■ NSF 18-306

U.S. R&D Increased by \$20 Billion in 2015, to \$495 Billion; Estimates for 2016 Indicate a Rise to \$510 Billion

by Mark Boroush¹

New data from the National Center for Science and Engineering Statistics (NCSES) within the National Science Foundation (NSF) indicate that research and experimental development (R&D) performed in the United States totaled \$495.1 billion in 2015 (table 1). The estimated total for 2016, based on performer-reported expectations, is \$510.0 billion. These numbers compare to U.S. R&D totals of \$454.0 billion in 2013 and \$475.4 billion in 2014. In 2008—just before the onset of the main economic effects of the national and international financial crisis and the Great Recession—the U.S. total was \$404.8 billion. (All amounts and calculations are in current dollars, unless otherwise noted.)

Adjusted for inflation, growth in U.S. total R&D averaged 1.4% annually over the 7-year period 2008–15, marginally behind the 1.5% the average pace of U.S. gross domestic product (GDP) over the same period (table 2). By comparison, the average annual rate of growth was notably higher in the prior 10-year period (1998–2008): 3.6% for total R&D, and 2.2% for GDP. In part, the smaller average pace of R&D growth in 2008–15 reflects the inclusion of the Great Recession years (notably, 2009 and 2010). If just the 5-year period of 2010 to 2015 is considered, the average annual pace of growth is 2.3%, compared to 2.2% for GDP (table 2). The growth of business

and sources of funding. Performers and funders include private businesses, the federal government, nonfederal government agencies, higher education institutions, and other nonprofit organizations.² Organizations that perform R&D often receive significant levels of outside funding. Furthermore, R&D funders may also be significant performers.

R&D Performers
The business sector continues to be by far the largest performer of U.S. R&D. In 2015, domestically performed business R&D accounted for \$355.8 billion, or 72% of the \$495.1 billion national total (tables 1, 3). The business sector's predominance in the composition of

2017

Women, Minorities, and Persons with Disabilities in Science and Engineering

National Center for Science and Engineering Statistics
Directorate for Social, Behavioral and Economic Sciences

NATIONAL SCIENCE FOUNDATION

- Special analytic reports
- Other reports: *National Patterns of R&D Resources*

Indicators Development and Production

- Planning, scheduling and management, and contracting
- Drafting (topic scan, data gathering, analysis, authoring, prepare figures, tables, and appendix tables)
- Review (editorial, substantive, and statistical)
- Composition (traditional and digital)
- Publication and IT systems
- Coordination and Outreach (pre- and post-release briefings)

Committee on National S&E Policy 2018 Retreat

**Current *Indicators* Ecosystem
Products, Purpose, and Challenges**

Beethika Khan, Program Director, SBE/NCSES

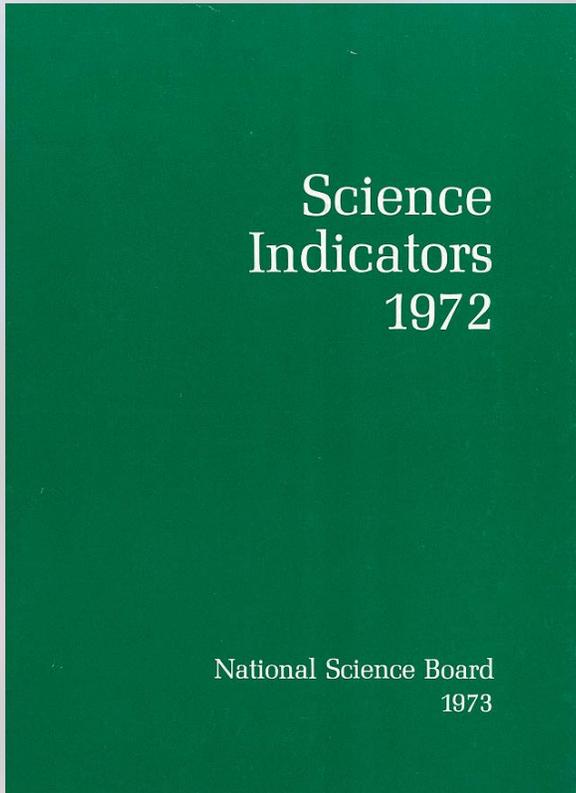
Indicators: Fulfillment of Statute

42 U.S. Code § 1863 - National Science Board

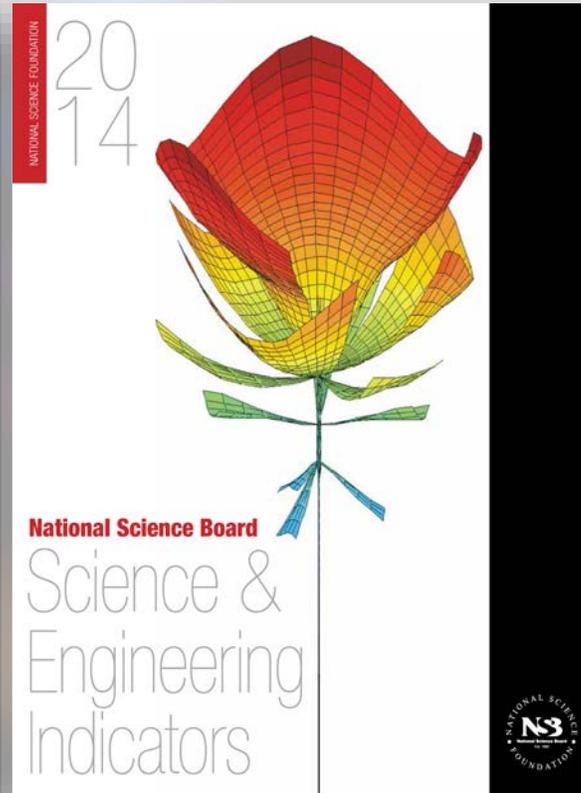
The Board shall render to the President and the Congress no later than January 15 of each even numbered year, a report on indicators of the state of science and engineering in the United States.



Expansion of Indicators



150 pages



1500 pages



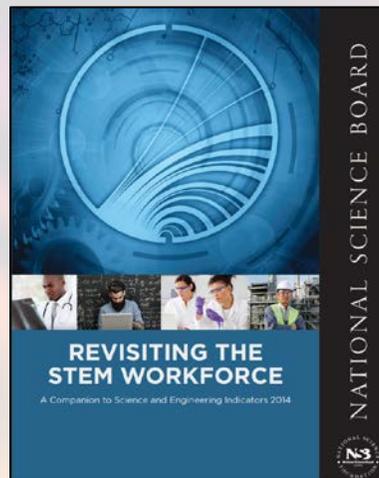
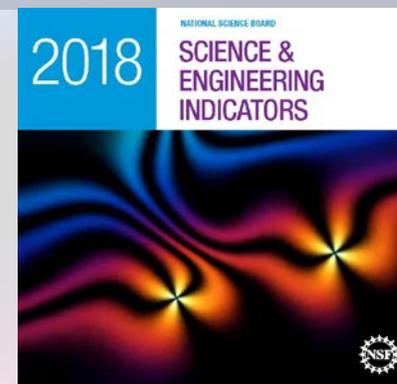
Born digital



Current *Indicators* Suite of Products

The screenshot shows the main navigation and content areas of the Science & Engineering Indicators 2018 website. It includes sections for the Full Report, Digest, Explore (Topics, Data Sources, Downloads), Data, Figures, State Indicators, Featured Content (Women in S&E occupations), and More from the National Science Board.

The screenshot displays the 'STATE INDICATORS 2018' page, specifically the 'Elementary and Secondary Education' section. It lists indicators such as Mathematics achievement (Fourth Grade Mathematics Performance and Proficiency, Eighth Grade Mathematics Performance and Proficiency), Science achievement, Public school expenditures, and High school credentials.



The screenshot shows the 'SEH DOCTORATES IN THE WORKFORCE, 1993-2013' website. It displays statistics for doctorates in all SEH fields in the workforce in 2003: 68% are engaged in R&D, 59% are employed outside of 4-year academic institutions, and 93% are satisfied with their jobs across all employment sectors. It also includes a section for 'Doctorates in All SEH Fields in the workforce, 2003' with a bar chart showing percentages for various fields.

- **Eight chapters:** education, workforce, R&D, academic R&D, publications, production and trade, innovation, public attitudes and understanding.
- **Overview, Digest, State Data Tool, *NSB Policy Companion* reports**



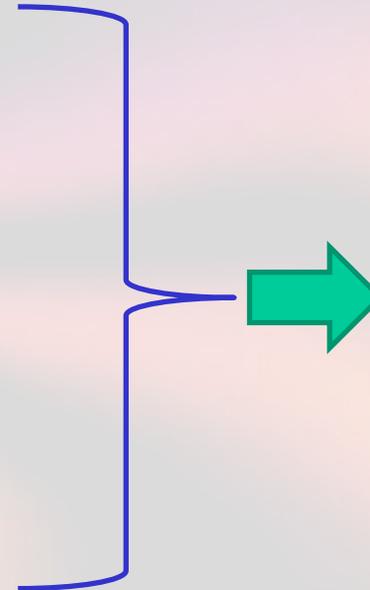
Indicators: Strategic Considerations

- ❖ **January 15 delivery**
 - ❖ **Policy relevant, policy neutral (main report produced by NCSES)**
 - ❖ **Balanced, unbiased**
 - ❖ **High quality data and analyses**
 - ❖ **Helps NSB and NSF to be part of the policy map**
 - ❖ **Wide and diverse audience: policymakers, researchers, media, public, international audience**
-  **Credible
and
authoritative**



Challenges for NCSES

- ❖ **Indicators: part of a large NCSES portfolio**
 - ❖ Utilizes many shared NCSES resources
- ❖ **Growing size and complexity**
- ❖ **Expanded digital presence**
- ❖ **Rigid, near-continuous production cycle to deliver entire report by January 15**
- ❖ **Product vs. process/scheduling challenges**



**Pressure
on NCSES
resources**

Challenges for NCSES: Product Coordination and Size

❖ *Indicators 2018*

- ❖ # chapters pages \approx 1065, appendix table pages \approx 1,800
- ❖ # figures \approx 300; appendix tables \approx 320; inline tables \approx 150
- ❖ # unique data sources \approx 73
- ❖ # expert reviewers \approx 67
(NOT including NSB and NCSES reviewers)
- ❖ # federal agency reviewers \approx 42

❖ Coordination across many individuals and offices

- ❖ NSB members, NSF and NSB staff, contractors, internal and external subject matter experts, other Federal science agencies, data providers

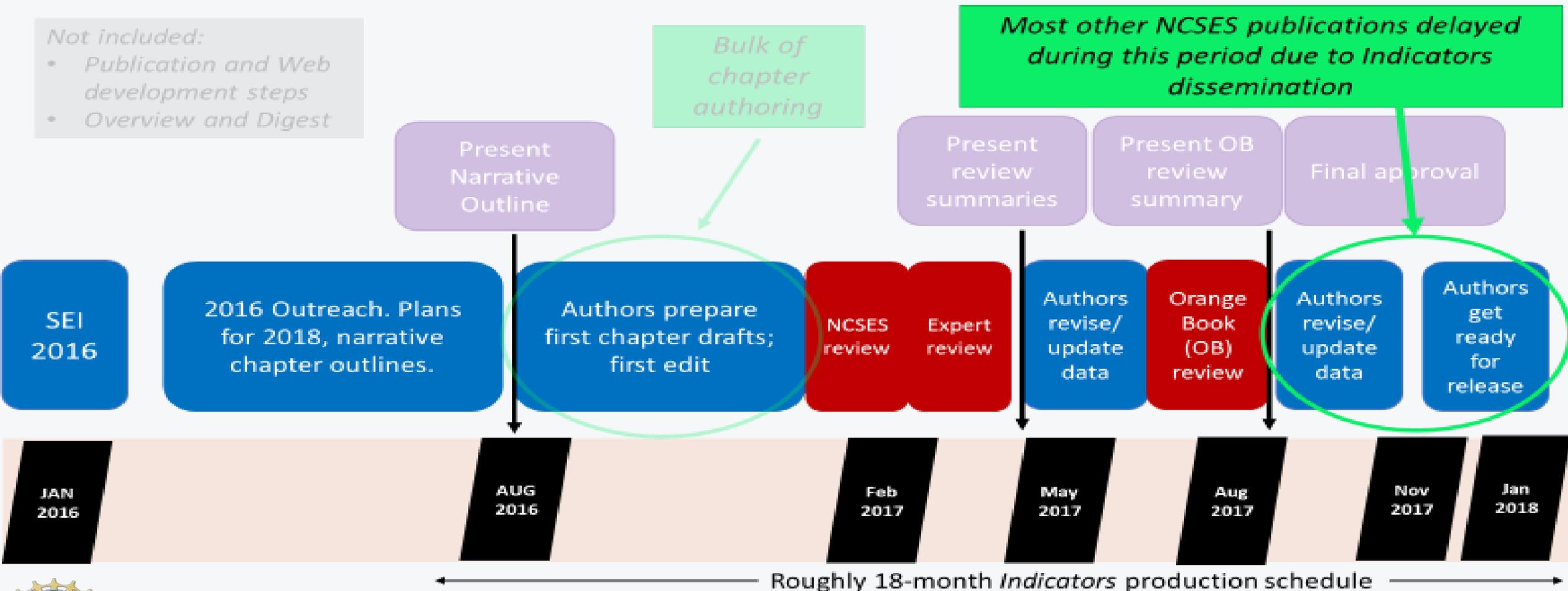


Challenges for NCSES: Process and Scheduling

Major Steps for *Indicators* 2018 Thematic Chapter Authoring

Not included:

- Publication and Web development steps
- Overview and Digest



Summary and Going forward

❖ Major challenges: Size and complexity

- ❖ Driver of schedule: January 15; Board meetings



- ❖ Impacts timeliness, usability, and relevance; overwhelms NCSES resources

❖ Opportunities

- ❖ Flow basis, production levelling
- ❖ Revisit: roles, responsibilities

❖ Understand

- ❖ What we value about the current products
- ❖ Shared vision, priorities, and objectives

