TA-METHODEN

U.S. Technology Assessment: Forum on Nanomanufacturing

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The recent U.S. technology assessment of nanomanufacturing used an expert-stakeholder forum as its central data source. This forum-based technology assessment (TA forum) was conducted by the U.S. Government Accountability Office (GAO) in response to a request from the Committee on Science, Space, and Technology, U.S. House of Representatives. Its purpose was to address the emergence of nanomanufacturing, its future, and its implications for U.S. competitiveness, the environment, and human health – and to inform congressional policy-makers and others.

The TA forum's methodology included four main phases:

1. prior to the forum, developing forward-looking nanomanufacturing industry profiles based primarily on interviews with experts;
2. organizing and conducting the forum – that is, inviting 26 experts, external to GAO, and GAO's Chief Scientist and Chief Economist to participate in the forum; developing the forum agenda; sharing the industry profiles with forum participants (pre-forum); facilitating forum discussions; and transcribing results;
3. after the forum, involving participants in developing the main TA forum report (GAO 2014a), which GAO used as the basis for both a summary booklet (GAO 2014b) and congressional testimony (GAO 2014c); and
4. distributing results to policymakers, interested professionals and stakeholders, and the general public.²

GAO's TA forum on nanomanufacturing most closely resembles the expert-stakeholder participatory TA, which van Eijndhoven and van Est

(2002, p. 211) define as a TA in which “experts or stakeholders become actively involved within the TA process”. They contrast this type of TA to both (1) the “classical TA” in which “only the researcher or expert is involved” and which produces a report “intended to provide [...] neutral, factual input to decision-making” and (2) the “public participatory TA” in which citizens are given a role and a voice. As explained below, many of the experts who participated in the forum were also stakeholders.

1 Brief Results

Forum participants viewed nanomanufacturing as an emerging set of developments that will become a global megatrend – a technological revolution that is now in its formative phases but is expected to burgeon in the years ahead, bringing new opportunities, “disruptive innovation”,³ job creation, and diverse societal benefits. Forum participants and other experts said that the United States likely leads in nanotechnology R&D today and in some areas of nanomanufacturing (for example, nanotherapeutic drug development and the design of semiconductor devices). However, they cautioned that the United States faces global-scale competition and is struggling to compete in some industry areas. Specific challenges to U.S. competitiveness in nanomanufacturing identified at the forum included: (1) a key U.S. funding/investment gap in the middle stages of the manufacturing-innovation process (see fig. 1) – a gap that in other countries, experts said, is generally not as significant or is being addressed; (2) the lack of a U.S. vision for a nanomanufacturing capability; (3) extensive prior U.S. offshoring in certain industries or U.S. loss of an industry,⁴ either of which (offshoring or loss) can make it difficult to establish new, widespread U.S. nanomanufacturing in affected industries; and (4) threats to U.S. intellectual property. A related topic concerns lack of international standards sufficient to effectively and efficiently conduct commerce or address environmental, health, and safety (EHS) issues.

Fig. 1: Funding/Investment Gap in the U.S. Manufacturing-Innovation Process

Source: GAO adapted from Executive Office of the President 2012, p. 21

Forum participants suggested three approaches to enhancing U.S. nanomanufacturing competitiveness by indirectly or directly addressing the U.S. funding/investment gap and other issues:

- strengthening U.S. innovation by updating current innovation-related policies and programs,
- promoting U.S. innovation in manufacturing through public-private partnerships, and
- designing a strategy for attaining a holistic vision for U.S. nanomanufacturing.

For each approach bulleted above, participants delineated proposed actions and a supporting rationale. They voiced diverse views about the relative utility of each approach (see GAO 2014a, p. 42–54). However, the three approaches might also be seen as complementary.

Varied forum participants also suggested (1) developing international nanomanufacturing standards for commerce, (2) maintaining U.S. support for basic nanotechnology R&D, and (3) developing a revitalized, integrative, and collaborative approach to EHS issues.

2 GAO Technology Assessment Method (TA Forum)

Since 2002, GAO has conducted Comptroller General Forums on a wide variety of policy issues facing the nation. Experts, who in many cases are also stakeholders, are invited to express and exchange views within a structured agenda. Forum discussions are recorded and transcribed, and GAO subsequently publishes

a report describing them. Participants are listed in the report of the forum, but specific views are not attributed to any individual. GAO's forum on nanomanufacturing followed this general model. Additionally, the nanomanufacturing technology assessment (TA forum) involved four key methodological elements or phases, as described below.

- *Developing four industry profiles prior to the TA forum:* GAO designed a pre-forum reading package that featured four forward-looking, expert-based industry profiles to establish a common “grounding” for forum discussions and support the framework of the forum agenda.⁵ The profiled nanomanufacturing industry areas include: (1) semiconductors, (2) advanced batteries for vehicles, (3) nano-enhanced concrete, and (4) nanotherapeutics in medicine (see GAO 2014a, p. 79–98). Each profile was designed to cover the topics that framed the forum agenda.
- *Organizing and conducting the TA forum:* The forum agenda (GAO 2014a, p. 68–71) was designed to (1) cover key topics, (2) elicit and share each expert's views and knowledge (through brief presentations or commentary), and (3) encourage interdisciplinary dialogue (through general discussion sessions). GAO selected forum participants with the assistance of the National Academies.⁶ In selecting participants, the goals were to (1) include expertise relevant to key topics; (2) include a range of perspectives and, to the extent possible, a balance of views in potentially controversial areas such as innovation policy and environmental issues; and (3) represent academia, industry, government, and other sources, such as nonpartisan think tanks. More generally, we recognized that participants were selected because they were on the cutting edge of nanomanufacturing issues and would, in many cases, be in positions to benefit from government support of nanotechnol-

ogy or nanomanufacturing. That is, many forum participants were both experts and stakeholders. GAO therefore highlighted this fact in reporting on the forum.⁷

- *Developing reports of the TA forum – and involving forum participants:* GAO staffers initially drafted a summary based on transcribed forum discussions, participants' slide presentations at the forum, and information developed for the four industry profiles. We then asked all forum participants to review and comment on the draft summary; 23 of the 26 external forum participants replied.⁸ Most said that overall, the draft summary captured forum messages. However, many added to their forum remarks or suggested bibliographic references; we incorporated their suggestions, as appropriate. GAO officials and two external experts, who were not forum participants and with whom GAO had not previously communicated about the forum, reviewed the final draft.⁹ Two subsequent GAO publications were developed from the main report: (1) a printed summary booklet (GAO 2014b) and (2) congressional testimony by GAO's Chief Scientist (GAO 2014c).
- *Disseminating TA forum results to three key groups:* GAO and its staff have communicated TA forum results to three key groups – congressional policymakers, experts and stakeholders, and the general public. Dissemination to congressional policymakers included delivering the main report (GAO 2014a) to congressional requesters, subsequently emailing the report to other relevant congressional committees, and testifying at a congressional hearing (GAO 2014c); the booklet summarizing the TA forum (GAO 2014b) was also made available at that hearing. Dissemination to experts and stakeholders was achieved, first, by emailing the main report to forum participants, other experts/stakeholders whom GAO consulted, authors cited in the main report, and relevant organizations (such as the NanoBusiness Commercialization Alliance); second, by presenting findings at professional meetings (for example, Armes 2014; Persons 2014a; Persons 2014b; Persons 2014c; Persons 2014d; Per-

sons 2014e; Persons 2014f); third, by writing an invited online editorial for Scientific American (Persons 2014g); fourth, by distributing the booklet at presentations;¹⁰ and fifth, by preparing this invited article. Dissemination to the general public has, thus far, included making the nanomanufacturing TA forum reports available on the GAO website, presenting a brief synopsis of this work in the GAO WatchBlog,¹¹ and describing results on a local TV program. We are currently developing further dissemination strategies.

- Finally, the dissemination described above is being extended by others in online blogs or other communications – for example, Bergeson 2014, Caprio 2014, Johnson 2014, McDermott 2014, Nanotechnologies Industries Association 2014, The Economist 2014, and Tyrrell 2014.

Notes

- 1) The statements in this article are those of the authors and do not necessarily reflect the position of the U.S. Government Accountability Office.
- 2) Writing in a foresight context, Saritas et al. (2013) emphasize involving or disseminating results to multiple groups, such as policymakers, experts and stakeholders, and the general public.
- 3) “Disruptive innovation” refers to a new technology that creates a new market (and a new value chain or “value network”) and that ultimately, and often unexpectedly, overtakes an existing technology (see Christensen/Raynor 2003). For example, innovations such as the Ford Model T automobile production line have been described as creating new markets, displacing earlier technologies, and in some cases, creating jobs.
- 4) One example of U.S. loss of an industry would be lithium-ion batteries for hybrid and electric vehicles. As background, the underlying research on lithium-ion batteries was first conducted in the United States; however, smaller lithium-ion batteries for consumer electronics have long been manufactured in Asia (rather than the United States), and Asian firms appear to have a competitive advantage in the manufacturing process – which is similar for small and large batteries. However, one expert said that if, in future, new kinds of vehicle batteries require different manu-

facturing processes, the current Asian advantage could become less significant.

- 5) Altogether, GAO consulted 37 diverse experts *in addition to* those selected as forum participants (GAO 2014a, p. 75–78). Many of these experts were also stakeholders; that is, many of them were in a position to benefit from government support of nanotechnology or nanomanufacturing. Therefore, when we sent forum participants the industry profiles, we included a caveat about other experts' possible stakeholder status.
- 6) Specifically, the National Research Council of the National Academies, Washington, D.C.; for more information about this organization see <http://www.nas.edu>.
- 7) Additionally, to increase our understanding of forum participants' potential conflicts of interest, we asked all forum participants to complete and sign a form, in advance of the forum, disclosing their perspectives and interests. A complete list of forum participants is presented in GAO (2014a, app. II).
- 8) GAO's Chief Scientist and Chief Economist, both of whom participated in the forum, also contributed to reporting on the forum.
- 9) Additionally, GAO staffers traced the accuracy of all statements in the final draft back to the forum transcript, communications with forum participants, pre-forum interviews with experts, and so forth.
- 10) GAO staffers distributed the summary booklet (GAO 2014b) at a presentation at "the WorldFuture 2014" conference (see Persons 2014f) and plan to do so at future conferences and presentations.
- 11) GAO created the WatchBlog in January 2014 to highlight existing GAO work in a conversational tone appropriate for the general public; it is available on the public GAO.gov website.

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