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Perspective

US–Czech conference strengthens bilateral and multidisciplinary collaborations in nanotechnology and chemistry

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Abstract

There are several methods to encourage bilateral and multidisciplinary collaborations—the most oft-used and effective include technical conferences, workshops, and seminars with the optimal combination of people, agenda, and length. However, this balance is difficult to attain, especially for meetings across academic disciplines and geographic borders. For nearly two decades, the US National Academies have developed a series of bilateral meetings to bring together scientists in different countries, which appear to have addressed such challenges via concise meetings with select emerging leaders from disparate fields and sectors. The authors utilized a similar approach to promote US and Czech collaborations in nanotechnology, given their mutual investments in the area and interests in building relationships. The bilateral meeting was held in Prague and designed to focus on nanotechnology and chemistry. The goals were four-fold: (1) evaluate US and Czech capabilities and challenges in nanotechnology and chemistry, (2) identify likely research projects and funding sources for collaborations, (3) celebrate 100 years of US and Czech diplomatic relations, and (4) increase government and public support for bilateral scientific research. The two-day meeting was named the *US–Czech Conference on Advanced Nanotechnology and Chemistry*. A summary of the research presentations, funding opportunities, panel discussions, and potential joint projects are given herein. It is our hope that this perspective will facilitate similar bilateral meetings in other fields to promote more multidisciplinary research.

Keywords: US–Czech bilateral meeting, nanotechnology, chemistry, multidisciplinary research

(Some figures may appear in colour only in the online journal)

The multidisciplinary nature of nanotechnology is evident from a cursory review of its prolific history. Although simplistic, it is convenient to discuss the various stages and participants in nanotechnology per the following eras: conceptual idea phase, basic discovery phase, research and development phase, and commercialization phase. In retrospect, the conceptual idea phase could have commenced with Feynman's lecture 'There's Plenty of Room at the Bottom' in 1959 [1], but this is still a matter of debate [2]. Others point to the inception of the term itself as the starting point—it was initially devised in 1974 to denote processing, separation, consolidation, and deformation of materials by one atom or molecule at a time [3] and later popularized in the 1980s via early scientific publications [4] and books [5]. These basic ideas led to the discovery phase in the 1980s, which was predicated on two developments: the inventions of the scanning tunneling microscope [6] and atomic force microscope [7] and the advent of several nanoscale materials (e.g. fullerenes [8] and carbon nanotubes [9]) and manipulation schemes (e.g. moving atoms to form a predetermined logo [10]). The new metrologies and materials provided the impetus for the research and development

phase in the 1990s. This phase was advanced largely by academic institutions and government programs. The academic institutions were responsible for much of the underlying research and personnel training, which was achieved through new organizations, books, university courses, conferences, journals, and research centers. However, this growth was only possible with government support and funding; the most notable example was through the US National Nanotechnology Initiative, which sought to advance a world-class research and development program, foster the transfer of new technologies to industry, develop and sustain educational resources and a skilled workforce, and support responsible development. This prevalent support enabled nanotechnology to grow beyond its roots and attain 'convergence' across a wide range of disciplines including materials science, physics, chemistry, biology, mathematics, and engineering [11]. The convergence not only resulted in new areas of research, but also aided in pushing nanotechnology into the commercialization era. An early feature paper summarized the litany of commercial prospects; interestingly, several of the highlighted examples have now reached commercial success, including microfluidic capillary devices for nucleic acid and protein research (LabChip®, PerkinElmer), liposome-based products for cancer therapeutics (Doxil®, Johnson & Johnson), and quantum dot technologies for displays (QDEF®, Nanosys) [12]. However, the author also noted that future products will require continued support from academic institutions and government programs, robust production and large-scale manufacturing, and rigorous safety studies. In turn, this will require more multidisciplinary research across disciplines and geographic borders, as these collaborations will generate the new ideas required to address the remaining impediments.

There are several methods to encourage such collaborations—the most oft-used and effective include technical conferences, workshops, and seminars with the optimal combination of people, agenda, and length. However, this balance is difficult to attain, especially for meetings across academic disciplines and geographic borders. For nearly two decades, the US National Academies have developed a series of bilateral meetings to bring together scientists in different countries, which appear to have addressed such challenges via concise meetings with select emerging leaders from disparate fields and sectors. The authors utilized a similar approach to promote US and Czech collaborations in nanotechnology, given their mutual investments in the area and interests in building relationships. This approach was initially adopted by the latter three authors after discussions with US and Czech scientists about their desired format and subsequently validated by the lead author during an Embassy Science Fellowship. The authors secured funding from US and Czech agencies to provide financial support for the invited scientists and the meeting venue. The bilateral meeting was held in Prague and designed to focus on nanotechnology and chemistry. The goals were four-fold: (1) evaluate US and Czech capabilities and challenges in nanotechnology and chemistry, (2) identify likely research projects and funding sources for collaborations, (3) celebrate 100 years of US and Czech diplomatic relations, and (4) increase government and public support for bilateral scientific research. To realize goal (1), we invited 30 well-respected US and Czech scientists from different fields and sectors to attend the meeting for the full two-day span and provide research summaries on capabilities and challenges. On goal (2), we designed the agenda with formal and informal discussion periods and invited funding agencies with bilateral programs, with the overarching aim to facilitate funding opportunities for joint projects. For goal (3), we requested and received significant help from both the US and Czech governments; the event was hosted by the US Embassy, attended by several high-level government officials from both countries, and celebrated with the US Ambassador to the Czech Republic via a reception at his official residence. Finally, goal (4) was addressed by the US Embassy Public Affairs Office through a public awareness campaign for the conference on social

Figure 1. Photograph from the US–Czech Conference on Advanced Nanotechnology and Chemistry.

and traditional media. The two-day meeting was named the *US–Czech Conference on Advanced Nanotechnology and Chemistry*. A summary of the research presentations, funding opportunities, panel discussions, and potential joint projects are given below. Figure 1 is a photograph of the participants on the second day of the meeting.

The first day began with brief comments from high-level government officials and meeting organizers and funding agencies. US Ambassador Stephen King noted that one of his priorities was to enhance economic relations between the countries through professional exchanges, collaborative projects, and commercialization of innovative technologies. These ideas were reiterated by Czech Republic Deputy Minister Pavel Doleček, which ratified the meeting goals and highlighted their significance in moving nanotechnology forward. The meeting progressed to the research summaries, with the introductory lectures focused on emerging areas. The first lecture reviewed the synthesis, structure, and properties of two-dimensional metal carbides and nitrides, which represent a new class of materials with tunable properties for energy storage and a litany of other applications [13]. The second lecture focused on two-dimensional arrays of dipolar molecular rotors, both for fundamental investigations on collective behavior and possible utility in analog electronics [14]. This transitioned to a session on biomedicine. The first lecture demonstrated a history of success in US–Czech relations—the discovery and development of acyclic nucleoside phosphonates was marked as a bilateral effort that launched a new class of antiviral drugs [15]. The subsequent lectures focused on the treatment of diseases: nanoparticle-loaded cells and exosomes for brain diseases [16], stimuli-responsive polymers for neoplastic and inflammatory diseases [17], and ultra-low fouling zwitterionic materials for various treatment platforms [18]. This led to a session on nanophotonics, biosensing, and graphene. The first lecture on nanophotonics highlighted materials and approaches for dynamic infrared optics, and showed that subdiffraction confinement of light can be achieved with polaritonic materials and nanostructures [19]. The subsequent lectures on biosensing revealed new optical methods to detect and characterize specific molecules on gold nanostructures—the first permitted the detection of DNA at unprecedented concentrations [20], while the second probed the structure of surfactant layers and lipid bilayers and the positions

and orientations of their molecules [21]. The final lectures on graphene showcased the chemistry and properties of carbon allotropes [22] and their derivatives [23], with an emphasis on unique properties and potential impacts to bioimaging, electronics, and energy. The final session was on advances in nanoscale imaging through scanning probe microscopy and electron microscopy. The first two lectures illustrated that the former tool can attain molecular-level details of hydration processes [24] and quantum states [25], while the final lecture proved that the latter tool can build quantum materials from scratch [26]. The day concluded with a reception at the residence of the US Ambassador, which provided participants and guests an opportunity to discuss the lectures and potential collaborations.

The second day began with a brief overview from the meeting chairs and then immediately progressed into a session on electronics and spintronics. The first lecture on spintronics outlined several ways in which ferromagnetic materials have transformed sensing, memory, and logic applications, and hinted at how antiferromagnetic materials are poised to make great advances in the high-speed operation of such devices [27]. The subsequent lectures focused on the synthesis and properties of nanostructures for myriad electronics applications—the first used semiconductor nanowires and nanochannels as the basis for biosensors and nanoionic devices [28], the second utilized superconducting nanowires to generate photon-number-resolving imagers and sensors [29], and the third utilized semiconductor nanocrystals and nanorods to facilitate photoluminescence from visible to near-infrared wavelengths [30]. This led to a session on advances in the chemistry of molecules and materials, which ranged in scope from new synthesis and characterization methods to novel application areas. In more detail, the lectures focused on new routes for the synthesis of metal amidinate and guanidinate complexes [31], the characterization of reaction intermediates by ion spectroscopy [32] and host-guest and protein-ligand complexes by computational methods and benchmark calculations [33], and the application of such methods to study the formamide-based origin of life scenario [34]. This led to a session on environmental and catalytic technologies, which clarified the role nanotechnology can play in industrial applications and environmental remediation. The lectures examined a wide range of topics: magnetic and carbon-based nanomaterials for green chemistry [35], 'unfeasible' zeolites for catalysis, adsorption, and separation [36], iron nanoparticles for groundwater remediation [37], and metal nanostructures for energy, catalysis, and biotechnology [38]. This transitioned to perhaps the most important session of the meeting, which included brief overviews from government officials on the US–Czech Science and Technology Agreement (STA) and funding opportunities for US–Czech collaborations. The lectures on the STA clarified the scope of the agreement, namely as a framework for cooperation with mechanisms for dispute resolution and intellectual property allocation, but not as a guarantee for increases in science and technology projects or an instrument to allocate funding. The lectures from funding agencies (NSF, ONR, ONR Global, and Army RDECOM-Atlantic on the US side and TAČR, GAČR, and Technology Center ASČR on the Czech side) provided general information on histories, missions, and budgets and more detailed information on bilateral funding opportunities. The lectures were followed by a panel discussion, which enabled participants to ask STA and funding questions and define roadblocks to partnerships. Finally, the meeting was adjourned, and guests were invited to a final networking dinner.

Overall, the meeting chairs and participants viewed the meeting as a huge success, given its ability to concisely address each of the four goals defined above. On goal (1), the meeting clearly showed that both countries have dedicated significant resources to the growth and development of nanotechnology programs, as exemplified by the continued research and personnel training from academic institutions and support and funding from government agencies. On goal (2), the meeting immediately provided a list of potential joint projects, which included

work on applied molecular evolution, dynamic control of catalyst structure, active infrared nanophotonics and optics, and graphene with tailored impurities. In addition, the funding agencies highlighted programs that could foster such projects through travel, workshop, and research grants (e.g. IRES, REU, PIRE at NSF, Visiting Scientist Program at ONR Global, Delta Program at TAČR). On goal (3), the meeting was the first program supported by the US Embassy Centennial Grant Fund; the fund financed thirty projects, each of which showcased a different facet of the US–Czech relation. Moreover, the US–Czech STA was recently renewed for another ten years; in the agreement, both countries confirmed their intention to develop, support, and facilitate scientific and technological cooperation. On goal (4), the meeting included interviews with conference scientists on Czech national television and coverage from a major Czech newspaper. Despite these feats, US–Czech collaborations are still underrepresented in the scientific community, and will only reach their full potential through the continued expansion of bilateral funding and exchange programs. For instance, most agencies are currently limited in their ability to fund both sides of a project. The launch of truly joint funding prospects would entice researchers to formalize relationships and provide a mechanism for multidisciplinary research. Another area for potential growth is through student awareness and exchange programs. A recent feature paper and a lecture on the second day noted one such effort: National Nanotechnology Day [39]. Other activities include Fulbright US and Foreign Student Programs, which enable cultural exchange through interactions inside and outside of the classroom. Finally, this meeting was meant to be the first in a series, with future meetings focusing on different areas (e.g. artificial intelligence). The continuation of these meetings will cultivate additional US–Czech ties, and could enable focused journal collections with contributions from emerging investigators [40]. In summary, the future of nanotechnology is bright, with a recent report pointing to over 1600 consumer products in industries ranging from healthcare to electronics [41]. However, to proceed further into the commercialization phase, added emphasis must be placed on the underlying multidisciplinary research, which is only possible via interactions on the global stage.

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