Preface: Converging technologies from the nanoscale require enhanced ethics

Reaching the atomic and molecular levels with investigative and transformative tools has been a historic turning point not only for human knowledge but also for philosophy, manufacturing, and human well-being. The rapid progress of nanotechnology has been mirrored by increased concerns about unknown material behavior, powerful transformative tools, human-technology coevolution, and other societal implications.

Developments at the nanoscale have awakened other foundational science and technology fields such as modern biology, information technology, wireless technologies, artificial intelligence (AI) systems, and cognitive technologies. Together, these are transforming ways of life and societal trends. A new, converging science and technology global platform— nano-bio-info-cogno-AI —has been created worldwide. This platform built from the nanoscale is accelerating economic and human development. Risks of secondary effects on “environmental, health and safety (nano-EHS)” and “ethical, legal and societal implications (nano-ELSI)” must be identified and mitigated from the beginning of any large project, in concurrence with the science and technology progress of the respective projects.

Significant nanoscale science and technology research programs continue around the world; once President Bill Clinton announced the U.S. National Nanotechnology Initiative (NNI) in January 2000, national programs sprang up in 80 other economies within just a few years. These programs are pushed by successive nanoscale breakthroughs and convergence with other emerging science and technology fields. Programs also are pulled by their extensive and multifaceted societal benefits, which were recognized early; nanotechnology stakeholders convened on the topic within the first month of NNI, leading to the report, “Societal Implications of Nanoscience and Nanotechnology” (Kluwer, now Springer 2001). The NNI’s cumulative research and development funding has reached about \$28 billion in 2019. Between 2000 and 2019, the average annual growth rate of nanotechnology publications has been about 14% (faster in the first decade, decelerating slightly after 2010) and of nanotechnology applications of about 25% (accelerating after 2010). Societal implications grew with several kinds of applications, such as those related to human and environmental safety and ethical and legal aspects. Global revenue of products having nanotechnology as the key competitive factor is estimated to reach about \$3 trillion in 2020, of which about one quarter is from the U.S. New areas of research and engineering such as metamaterials and plasmonics have emerged, and new uses appear in emerging technologies such as molecular manufacturing, regenerative medicine from the nanoscale, and smart phone platforms. Recent R&D programs are directed to future nanosystem architectures and converging technology platforms for production, health, infrastructure, and services. Today, responsible governance focuses attention on the confluence of nanotechnology with other domains,

its role on social sustainability, and synergistic effect from integration with other emerging technologies (“Converging Knowledge, Technology and Society: Beyond Nano-Bio-Info-Cognitive Technologies”, Springer 2013, available on www.wtec.org/NBIC2/).

As part of this worldwide effort, an international community has been established for nano-EHS and nano-ELSI. This has been facilitated by the creation of large networks in the U.S., Europe, and Asia, beginning with the networks on “Nanotechnology in Society” (centered at the UC-Santa Barbara and Arizona State University) and “Centers for Environmental Implications of Nanotechnology” (at UCLA and Duke University). After an initial focus on the toxicity of nanomaterials themselves, scientific interest in nanodevices and exposure of industrial and incidental nanoproducts to consumer has risen and led to essential improvements in evaluating and governing the risk. Significant research and regulatory activities have addressed the environmental, health and safety implications of nanotechnology applications, especially for passive as well as chemically and biologically active nanoparticles. Responsible development of nanotechnology increasingly addresses ethical, legal, and other societal issues, including ecological and human development aspects. Ethical questions have been raised about who will receive the benefits of nanotechnology and who will be affected by its secondary effects. Ethics need to be included in the vision of an R&D program in an emerging area. Based on my experience in planning research initiatives, on average about a third of the overall program’s success depends on the initial topic selection, research directions, and consideration of societal implications, including ethical aspects.

The next decade will bring several main advancements to nanotechnology-inspired science and technology fields. Larger and multifunctional nanostructures and devices already are being built with more atoms, complex networking, and information content, increasing the EHS and ELSI risks. They are increasingly used in advanced manufacturing, quantum information systems, AI systems, the bioeconomy, neurotechnology, sustainable society, and advanced wireless S&T. Such technologies will converge to better serve people and contribute to human development, but new safety concerns may arise. Nanoscale science and technology evolve closer together, with more partnerships between academia and the private sector. Translational nanotechnology takes a center stage. The necessary infrastructure becomes more complex and integrated with the needs of the global emerging technology system. A flexible nanotechnology workforce education and training are essential requirements for safe and sustainable progress and along-term challenge strongly connected to changes in the human-technology ecosystem and other societal trends.

With the prospect of these and other emerging, convergent areas of nanotechnology before us, the need to incorporate ethics – for both program success and positive societal impacts – is clear and crucial

The “Handbook on Nanoethics” assembled by Marcel Van de Voorde and Gunjan Jeswani bring together a rich range of topics and various perspectives from five

continents. The book presents highlights of ethics in nanotechnology (Chapter 1) and ethical reflections of nanotechnology (Chapters 2–6). Essential aspects of Health, environmental and industrial nanoethics are systematically presented (Chapters 7–11). Nanotechnology governance including societal and legal aspects are discussed in the last part of the book (Chapters 12–17). The co-editors provide guiding remarks and recommendations to nanotechnology providers and users. The collection of opinions presented in this volume is a remarkable selection of research contributions concerning the ethics of nanotechnology research.

This book brings together some of the most vigorous minds active in nanotechnology ethics in the world. Converging and emerging technologies from the nanoscale bring new health, environmental, ethical, and legal concerns that are highlighted in these volumes. We encourage all research, education, and industry experts to closely read these state-of-the-art contributions on ethics in nanoscale science and technology fields.

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