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## LETTER TO THE EDITOR

Sir,

We appreciate Dr Holt's commentary<sup>1</sup> on the CRN Task Force's collection of essays. Although many of his points are well taken, we would like to clarify a few misunderstandings and address a few disagreements.

Dr Holt states that "The use of the word 'nanotechnology' here includes ... the advent of true artificial intelligence." Although advanced nanotechnology should enable AI research and development, leading to concerns about AI as a major second-order effect, molecular manufacturing neither depends on nor implies the development of "true" artificial intelligence.

CRN disagrees with Dr Holt on the likely timeline of development of molecular manufacturing. Many sub-fields of nanotechnology, including medical applications, deal with amazingly complex systems and phenomena; by contrast, molecular manufacturing is largely a combination of mechanical engineering and chemistry, with most of the high-level functionality derived from computer control rather than from complex applications of physics. Even if molecular manufacturing takes twenty years to develop, the creation of wisely structured international institutions could take at least that long.

Dr Holt's discussion of funding impetus for molecular manufacturing may be countered by the observation that it only takes one nanofactory to launch a revolution. Once the first nanofactory is developed, exponential growth in production and impacts does not require additional nanofactory R&D, but mere duplication of nanofactories—using nanofactories as the means of production. As a general-purpose manufacturing system, nanofactories could find footholds or niches in a wide range of industries and applications, then rapidly become central according to the power of their products—and that power would be substantial, thanks to the higher performance of small machines.

Dr Holt correctly notes that the approach generally favoured by the CRN Task Force is not fully consistent with recent US actions. The CRN Task Force is intentionally an international group, with members from five continents. The question of how to get the US or any other nation to support policies with global benefits requires urgent attention and a sensitive exploration of long-term national self interests. Developing this analysis, and building national contacts who can implement thoughtful policy, will take a lot of time, effort, and forethought—another reason to start these explorations as soon as possible.

With regard to Dr Holt's concerns about energy and resources, efficient and inexpensive gathering of solar energy will be an early consequence of molecular manufacturing. Although any energy source will have ecological consequences, solar energy will certainly be able to power the manufacture of nanomachines in large quantities with lower impact than fossil sources. Because of the higher performance of nano-built materials and devices, as well as the

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<sup>1</sup> G.C. Holt, "CRN Task Force essays: a European commentary", *Nanotechnology Perceptions* **2** (2006) 167–170.

increased control of manufacturing operations, a nano-built product would require significantly less material input than the product it replaced. New applications could still lead to overconsumption, but for today's applications, molecular manufacturing is expected to have a much smaller ecological footprint than today's industries. New energy collection, transfer, transformation, and storage mechanisms should provide superior alternatives to fossil fuels. In fact, CRN recognizes the environmental benefits of molecular manufacturing as a substantial point in its favour.

We thank Dr Holt for his thoughtful response. Molecular manufacturing has the potential for both great good and great harm. Threading a course between the pitfalls will require years of study (see CRN's "Thirty Essential Studies"<sup>2</sup>) and additional years of implementation. We welcome and encourage ongoing dialogue with Dr Holt and others.

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<sup>2</sup> <http://CRNano.org/studies.htm>.