Collective Intelligence Systems for Science and Technological Convergences to Benefit Society[1]

For the Handbook of Science and Technology Convergence

by
Jerome C. Glenn, CEO
The Millennium Project

Abstract

Accelerating growth of scientific knowledge, technological advances, and their convergence makes it increasingly difficult for scientists, politicians, and the public to keep track of such changes and make informed decisions. Collective intelligence systems provide an alternative to relational databases, email networks, conventional websites, and social media. There are several definitions for "collective intelligence" and its applications. I define collective intelligence as an emergent property from synergies among three elements: 1) data/information/knowledge; 2) software/hardware; and 3) experts and others with insight that continually learns from feedback to produce just-in-time knowledge for better decisions than any of these elements acting alone. In addition to a brief overview of collective intelligence systems and why they are needed, this article will explain how The Millennium Project (MP) is creating its own collective intelligence system and how it can help scientists, politicians, and the public better understand change and participate in building and improving collective intelligence for S&T convergence.

Key words: collective intelligence; science and technology integration; Millennium Project; foresight; futures research; Global Futures Intelligence System

[1] This article is drawn in part from articles by the author in *Futura* 4/2009, *World Future Review* (Fall 2013), and *Technological Forecasting & Social Change* (2013) http://dx.doi.org/10.1016/j.techfore.2013.10.010

1. Introduction to Collective Intelligence

The term "intelligence" is used in this article to mean knowledge or information that informs action and as used in the sequence of understanding leading to wisdom: data, information, knowledge, intelligence, and wisdom.[1]

Collective intelligence could be the next big thing in information technology.[2] CISs are relatively new developments within the ICT world; and hence, alternative approaches for creating them are more often described online than in professional journals.[3]

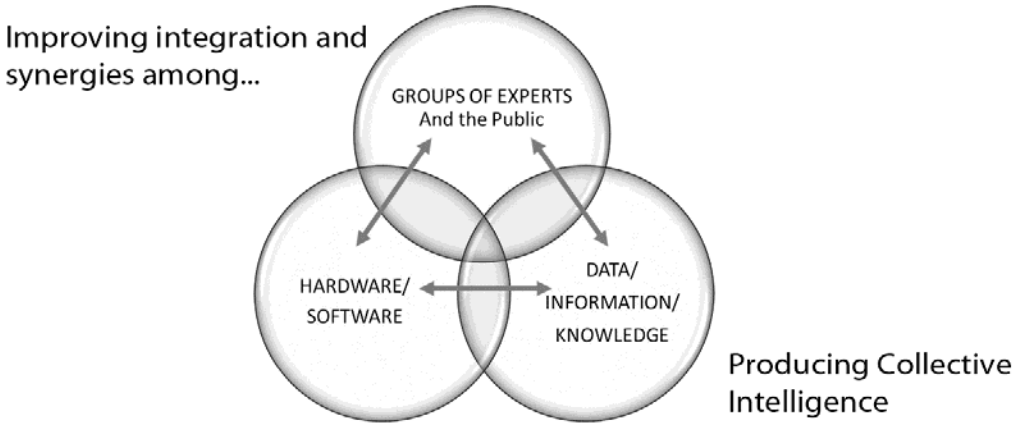
In the past, leaders would often gather wise elders and favorite consultants to discuss a problem until a solution was found. Then along came the Internet and Google, allowing leaders to have staff search through vast sources of information and distill these to provide intelligence for a decision. Meanwhile, the mathematically-inclined might say, "give me your data and I will build a model to help you make the right decision." All of these approaches have their value, so why not integrate them all into a system?

A collective intelligence system involves these three approaches, enabling each to improve the other in an ongoing feedback improvement system. I define collective intelligence as:

> *an emergent property from synergies among three elements: 1) data/info/knowledge; 2) software/hardware; and 3) experts and others with insight that continually learns from feedback to produce just-in-time knowledge for better decisions than any of these elements acting alone* (Glenn, 2009).

Hence, collective intelligence can be thought of as continually emerging from changing synergies among its elements, as illustrated in Figure 1.

Figure 1. Graphic illustration of three interactive elements of collective intelligence



A useful and efficient collective intelligence system should connect these three elements into a single interoperable platform so that each of these elements can change the others. Participants should be able to comment on any information or software or computer model in the system. These comments read by reviewers and editors can then lead to changes in the system. For example, new insights from a person in an online group discussion can lead to changes or edits in the text of some part of the information in the system. This change of text might illustrate the need for new decision-making software or changes in one of the online computer models or the requirement to add a link to a new online computer model. Running the new model could produce results that, when given to the appropriate discussion group, could stimulate additional discussions leading to better insight that would lead to new edits in a situation chart. Decision support software like Delphi could add to the mix and result in changes in the information in the system and help identify new experts to add to the discussion groups. These changes in turn can lead to new questions in a Delphi, which in turn can change the text of information in the system.

Many of the features of a collective intelligence system (CIS) have existed before, but their integration into one platform creates a different experience; just as telephones and computers existed separately before email, but once integrated, the email experience was unique. The elements of the European opera existed before, but their integration into one experience is quite different than experiencing its different elements separately. A CIS can be thought of as a

common platform of interlinked systems of people, information, and software each able to change due to feedback from the others.

There are already many different approaches to this subject. Some approaches to CI include: Pierre Levy of France focuses on the universal distribution of intelligence as the key element in *Collective Intelligence: Mankind's Emerging World in Cyberspace*.[4] Anita Williams Woolley, et al. explored the psychological factors that improve collective intelligence in groups in Evidence for a *Collective Intelligence Factor in the Performance of Human Groups*.[5] Francis Heylighen of Belgium has developed collective intelligence concepts to help the emergence of a "Global Brain" or "Global Brains" from the Internet.[6] He leads an international network to explore how to build a global brain at gbrain@listserv.vub.ac.be. MIT's Center for Collective Intelligence has created the *Handbook of Collective Intelligence* as a wiki for an evolving conversation of the theory of collective intelligence.[7] This center stresses the "peopleware" element of collective intelligence, looking at what characteristics are important in forming groups to best enhance their collective intelligence. The National Endowment for Science, Technology and the Arts in London has created a working draft discussion paper on collective intelligence as a Google Doc.[8] Even the United Nations has been considered as a future center for global collective intelligence through a series of meetings and papers (Ekpe, 2009).

Although one could consider Wikipedia, Google, crowdsourcing,[9] averaging expert judgments,[10] swarm intelligence,[11] and prediction markets[12] as examples of collective intelligence systems, these examples would not be a CIS by the definition offered in this article. They do produce information and in some cases, conclusions from a group, but they do not–so far–include feedback on a systematic on an on-going basis among the three elements to permit the continual emergence of new insights which then can affect other parts of their systems. They do not produce a continuous emergent intelligence, but only give a slice in time, whereas a CIS, like the mind, continually emerges and changes from the ongoing interaction of brain, experience, and environmental stimuli.

2. Some Historical Roots of Collective Intelligence Systems

Many efforts have been made to develop CIS over the years (Engelbart, 2008). In the 1960s, Doug Engelbart at SRI created software and hardware to augment collaborative decision-making.[13] The Delphi method was developed at the RAND Corporation in the early 1960's and has subsequently been used by many organizations.[14] The SYNCON was developed in the early 1970s by The Committee for the Future which integrated discussion groups, video and computer conferencing.[15] Murray Turoff's pioneering Electronic Information Exchange System (EIES), also in the 1970s, paved the way for new thinking about collective intelligence[16] and in the author's judgment provided the best example of a collective intelligence system at that time. The Wikipedia was created in 2001[17] and has grown to become the world's most successful—if not the first truly global—participatory information and knowledge system with more than 76,000 active contributors working on over 31,000,000 articles in 285 languages as of August 2014. All of these make it seem that the emergence of Pierre Teilhard de Chardins Omega Point[18] (integrated complexity and consciousness able to direct our evolution) and his popularization of Vladimir Vernadsky's Noosphere seem inevitable.

Thomas Malone defined collective intelligence at the opening of the MIT Center for Collective Intelligence in 2006 as "groups of individuals doing things collectively that seem intelligent."[19] Subsequently, the Center's website now lists its mission as: "How can people and computers be connected so that–collectively–they act more intelligently than any individuals, groups, or computers have ever done before.[20]" Thomas Malone and the MIT center continue to develop scholarly research on collective intelligence.

The Millennium Project has created collective intelligence systems for the Kuwait Oil Company (2003), the Climate Change Situation Room for Gimcheon, South Korea (2009), the Early Warning System for the Prime Minister's Office of Kuwait (2010), its own Global Futures Integration System (2012), and is now creating E-ISIS (Egypt's Integrated Synergetic Information System) for the Egyptian Academy of Scientific Research and Technology, which would be the first national CIS open to the public.

3. Collective Intelligence Systems Can Provide Support to Science and Technology Convergence

The accelerating complexity and the volume of change, with exponential increases in technological capacities and scientific knowledge, along with emerging interdependencies of economies, politics, and Internet-based groups, make it almost impossible for decisionmakers and the public to gather and understand the information required to anticipate potential convergences among scientific knowledge and technologies to make and implement optimal or sufficiently robust decisions.[21]

Because of such changes, the environmental, social, and security consequences of poorly informed decisions will have greater impacts tomorrow than they did yesterday. Hence, new systems for identification, analysis, assessment, feedback, and synthesis are urgently needed to inform decision-making. We need a more advanced system to think together about the future in some organized fashion so as to improve our collective prospects. We need a system to help us understand the global situation and prospects for the future that lets us interact with that information, discuss with colleagues, and use support software as need.

For example, the table below is an illustration of organizing technology convergence.

Table 1. Technology Convergence Table

Column items impact on rows	Nano-technology	Synthetic Biology	AI and robotics	Internet of Things	Computational Science	3-D Printing
Nano-technology	X					
Synthetic Biology		X				
AI and Robotics			X			
Internet of Things				X		
Computational Science					X	
3-D Printing						X

Each cell (without the x) could be the subject of an on-going Delphi; e.g., what are the impacts, convergent possibilities, etc. of nanotechnology on synthetic biology. As experts answer these questions, and feedback is given and responded to, a collective intelligence would begin to emerge on the potentials of convergences and impacts. Information in each cell would be hyperlinked for better visual, user friendly access.

One could also imagine a table of several approaches to one category. For example if there were five major approaches to nanotechnology, then a cross-impact matrix of five by five could be nested within one cells of the more general matrix above. Each main cell could have both the option of general converges of the general categories that might be accessible to the public, as above, as well as more specific sub-cells of elements within a category for more advance scientists and engineers. Vast and complex information would be available in an organized, user-friendly way for both the public and the professionals.

We lack systems that make it easy to see and update a situation as-a-whole: including current conditions and forecasts; desired situation with a range of views; and alternative policies to address the gap between what is and what ought to be. Instead, analysts often use the Internet to go from one source to other, becoming stressed by information overload.[22]

It is wise to get all the relevant information before assessing potential future S&T integration or making any informed decision, but it is increasingly difficult to organize all the positions, priorities, and strategies, in a way that brings more satisfactory coherence to our thinking and decision-making. Or as Leon Fuerth put it in *Anticipatory Governance*:

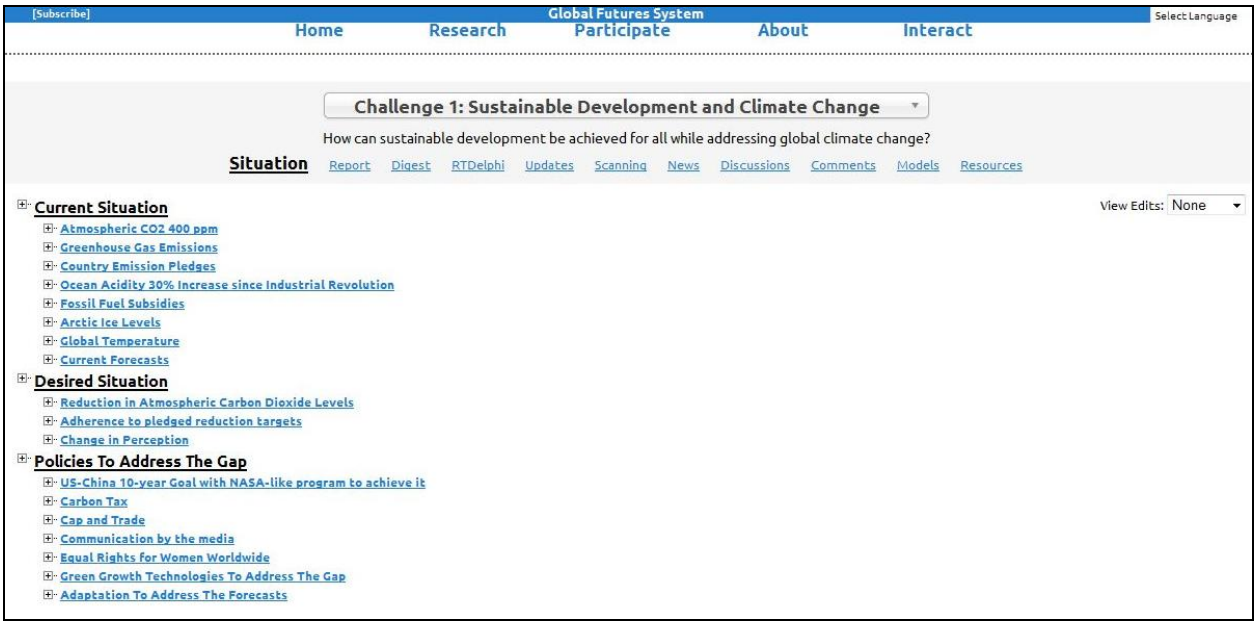
> *There are many sources of foresight available to decisionmakers originating both within and outside of the U.S. Government, but foresight is not methodical, continuous, or structured in a form that is useful for decisionmakers… A simple collective intelligence system (CIS) would manage content, organize expertise, track comments and changes in documents, and support prioritization.*[23]

Since everyone faces similar problems of managing complexity and change, we can expect to see the increased creation and customization of collective intelligence systems by governments, corporations, NGOs, universities, associations, and individuals. It has also been suggested that a collective intelligence system could provide continuity from one government administration to the next, "by making it easier to retain and transfer institutional knowledge that is essential for long-term strategic coherence, regardless of changes in policy or political philosophy.[24]"

Collective intelligence systems can also focus on specific issues such as climate change or industries like agribusiness. Just as spreadsheets have become a general tool that any organization or individual can use, so too, CIS could become a general tool adapted for an individual or organization, or a country, as in the case of Egypt to help "bring it all together."[25]

Figure 2 shows an example of a "Situation Chart" for organizing information to reflect the present and desirable situations related to a specific challenge, as well as the gaps to be addressed. Similarly to the entire system, it is continuously updated based on feedback and information gathered throughout the whole GFIS.

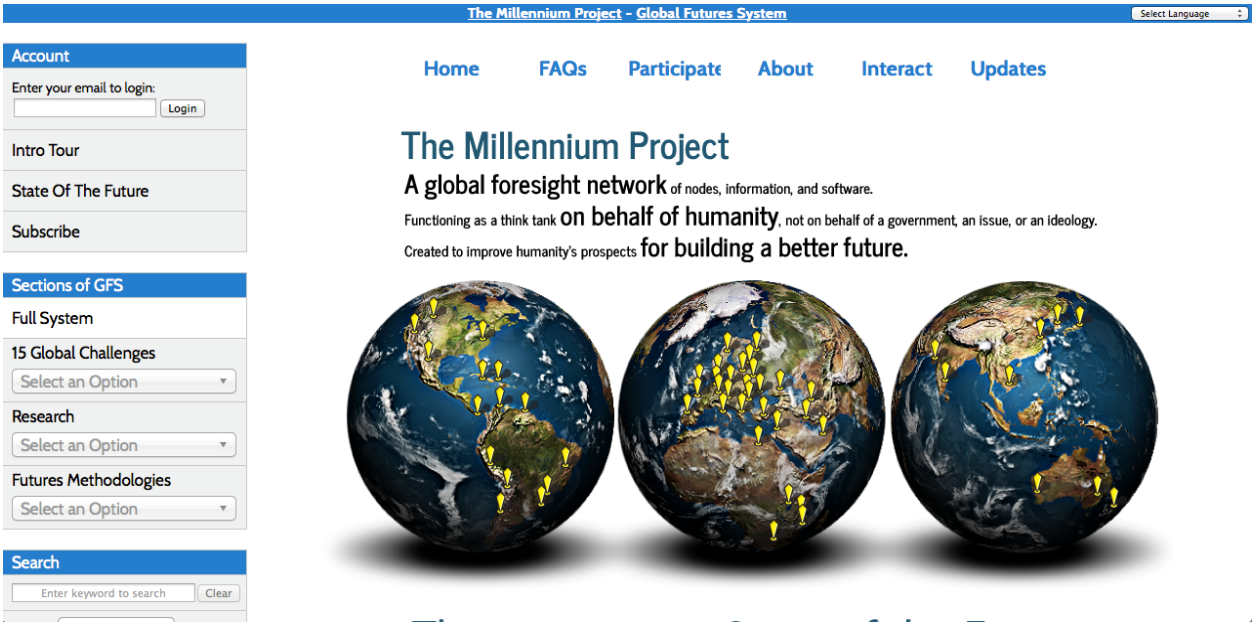
Figure 2. Example of a Situation Chart: Global Challenge 1. How can sustainable development be achieved for all while addressing global climate change?



4. An Example of a Collective Intelligence System used to support Global Futures Research

The Global Futures Intelligence System (GFIS) was created by The Millennium Project and launched at the Woodrow Wilson International Center for Scholars in Washington, D.C. in January 2013.[26] It is available at www.themp.org.

Figure 3. Front page of the Global Futures Intelligence System at www.themp.org



Using the GFIS platform alone, one can access internationally peer-reviewed chapters on 37 futures research methods, discuss with experts which methods to use, identify potential participants in the database, and send invitations to each. If a Real-Time Delphi is chosen, then it can be collaboratively designed, managed, results analyzed, reports finalized for downloading, all on one integrated platform.

GFIS is an example of the next generation of interactive technology to support those exploring global change and potential futures for humanity. It began by integrating all of The Millennium Project's 10,000+ pages of futures research obtained over the past 16 years from the annual *State of the Future* reports, plus information from expert listserv groups and its 50 Nodes (groups of individuals and institutions that connect local and global research and perspectives) around the

world. It also includes the *Futures Research Methodology version 3.0* with 39 chapters totaling some 1,300 pages of internationally peer-reviewed methods for exploring the future (37 chapters on specific methods plus an introductory chapter and a concluding chapter). All this, plus its software, are integrated in one platform so that users can participate to update and improve any element of this online collective intelligence system.

The most commonly used section is the 15 Global Challenges that helps see the potential convergence of science and technology but also its relationships and integration of other areas.

Table 2. Menu options for each of the 15 Global Challenges

Menu Option	**Function or explanation of the options**
Situation Chart	Current Situation, Desired Situation, and Policies to Address the Gap
Report	A short summary followed by more detailed information with access to relevant information, programs, and other related sources
News	Latest news items from RSS feeds automatically entered into the system with sources identified and with the ability for users to do key word searches to re-order the sequence, comment in a variety of ways, and to rate the relevance of each news item
Scanning	Important information added by users from the Internet, and other sources with the ability for users to annotate and comment on their significance. Bookmarklet software added to one's browser can be used for this.
Real-Time Delphi	To collect both expert and crowd sourcing opinions on each challenge. Questions may be added at any time. When a pattern of response is clear, the question can be deleted and the answers added to a situation chart and challenge reports
Questions	A blog-like area where the public and expert reviewers discuss questions they would like to explore, with the new ability for participants to re-edit their prior comments
Comments	The comment icon appears throughout the system, allowing anyone to add a

	comment, whether it is an item in the situation chart, challenge overview, resources, etc. These are organized by time and people can comment on other's comments
Models	Interactive computer models, mathematical as well as rules-based and conceptual
Digest	Dashboard of recent scanning items, discussions, new resources, and edits to the challenge by day, week, month, and year
Updates	Latest edits to the situation charts and reports, with sources that triggered them within each challenge and an update option for recent content additions in the whole system. It is also available from the homepage.
Resources	Links to websites, books, videos, presentations, and papers/articles

One of the greatest values of GFIS is that it serves as an interactive decision support dashboard, rather than just another source of information. It offers more than just new software tools—a vast body of intelligence/knowledge/data, and access to experts; it is also an evolving system for producing synergies among the three elements of collective intelligence (people, information, and software) that have greater value than the sum of their separate, individual values.

Everything in GFIS can be commented on by anyone who accesses the system. Substantive edits, updates, and improvements can be made in real-time by experts and the public via a rapid review process. GFIS reviewers will be notified automatically of any suggested edits within their expertise. Since reviewers are very busy, not expert in every detail of a challenge, and might not have seen the suggestion, it is assumed that of the one hundred reviewers per challenge, at least three will give their review of the suggestion to the relevant challenge within 24 hours. These reviews go to the GFIS editors who then make the edit.

Table 3. The types of participants, their roles, and how they are selected

Types of Participants	Access and Roles	How selected
1. Administrators	- Can edit text directly anywhere	GFIS Staff
2. Editors	- Can edit in selected challenges	GFIS Staff

	directly determined by permissions set by Administrators - Receives Reviewers' recommendations for edits.	Additional editors selected by monitoring GFIS activity
3. Reviewers Ideally about 100 per challenge[27]	- Receives edit suggestions from the public and other reviewers - Reviews/approves potential changes, sends recommendations or comments to editors.	Invited by GFIS staff, who will also notice excellent contributors and invite new potential reviewers
4. The Public	- Can access all information - Make text and data suggestions - Add comments anywhere in GFIS - Participate in Real-Time Delphi's, and discussion groups	Self-selected, Anyone

5. Examples of how one might use GFIS to better understand and anticipate science and technology convergence to benefit society

- **Select "Updates" of the whole system from the front page.** This gives all recent changes in scanning items, edits to reports and situation charts, RSS news aggregator, comments, discussions, questions, web resources, books, papers, and models. The results are displayed in an executive dashboard allowing one to go into further detail on any category and any item in a category. This can help one see how their interest fits into the larger whole. A specific term can be entered that returns the most recent matches.
- **Pose questions.** Results from the search can lead to new questions that can be posed in the relevant discussion groups or added as a structured question in a Real-Time Delphi setting specific demographic categories for analyzing the results. The categories could be

from non-scientist or non-engineer as well to get a broader range of views helping to anticipate potential convergences.

- **Conduct searches in specific challenges that might not seem related to a specific S&T item.** One could search within the global challenge on organized crime and find connections to S&T not previously considered. One can search by expert reviews inputs versus non-expert inputs to the system. These searches might bring up an important question that can be submitted to the discussion areas to obtain broader feedback and new insights from the group to the relevant challenge group. The discussion might generate several suggestions for updating or improving the text of the challenge's short overview. These suggestions are automatically sent to the reviewers of the challenge and then, if accepted and/or amended, are entered into the regular text of the challenge.
- **Create a Technology Converge Table to help anticipate S&T converges via integration of Cross-Impact Analysis and Delphi.** One example is explained above in Table 1. Technology Convergence Table that gives another way to gain new insights that might not have been known before.

GFIS is constantly evolving. Its collective intelligence will increase with the number of users, review and improvement of information, new software and models, and better integration of all these elements of a collective intelligence system.

Some conclusion is needed – even if only one paragraph. (following is just a suggestion – although probably too naïve and simplistic…)

A CIS not only makes S&T understanding and implementation easier, but it can also accelerate some new discoveries, as well as assess potential implications. Therefore, the positive ones can be better supported by relevant policies, research, and funding priorities, while the potentially negative ones could be further assessed to avoid unintended consequences.

The CIS could also make S&T understanding easier to the media and the public, for a better education and acceptance o new discoveries, while encouraging an open dialogue on research that could help build the best possible future to all.

End Notes

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[26] Video of the launch of GFIS: http://www.millennium-project.org/millennium/presentations.html or http://www.wilsoncenter.org/event/launch-the-global-futures-intelligence-system-and-the-2012-state-the-future-report

[27] Why so many reviewers? To make sure at least three review a suggestion within a day. The reviewers are very busy, are not expert in every detail of a challenge, and might not have seen the suggestion. Also, the reviewers are part of the discussion groups, RT Delphi panels, and other parts of GFIS to continually update and improve the collective intelligence.