Applying Complex Systems Engineering in Balancing Our Earth's Population and Natural Resources

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ABSTRACT

It is an old but urgent question: What is the viability of human life on Earth given that there are finite resources and an unlimited number of humans insisting on more than ample resources? Various forms of this question have been broached for centuries by many others. In this paper it is argued that the lack of truly long-term systemic thinking hinders consensus for taking serious action against overpopulation. Toward this end an attempt is made to apply the discipline of complex systems engineering in providing a new perspective to what we might do to ultimately prevent outrunning our Earth's resources.

INTRODUCTION

This paper is a follow-on companion to one on unlimited material growth (White 2012) that also used dialogue as a device for treating the problem and approaching potential solutions; some of that material is reflected here to capture the context. Table 1 introduces the characters involved in the ensuing dialogue. Each is intent on representing a broad segment of population in the world's more developed countries, particularly the U.S. Again, the papers' format incorporates a dialogue among fictitious interested parties to provide a balanced treatment and lively debate. The characters' opines display and highlight their passionate views. Obviously, you readers are free to decide to what degree these papers express opinions vs. scientific and/or engineering merit.

In many world cultures and religions people are taught from childhood that human life is sanctified. Throughout adulthood this ethical thought is reinforced continually through valiant attempts to save people from danger and respond to inevitable human tragedies by glorifying the victims of misfortune and showering compassion on their survivors. This mindset is so ingrained in our psyche that we unquestioning accept this the way to live. This surely seems fine because all reasonable people want themselves and others, especially their family, relatives, and friends, to thrive and be happy. However, consider whether this mantra can continue to serve us well for hundreds of more years let alone millennia. This paper explores whether we will continue to subscribe to the implied viewpoint – The more people the better! – (what the author, for one, believes to be a potentially insidious view) or gradually change our mindset for the long-term benefit of the human race.

Table 1. Description of the characters

Character Name	Character Type	Role in Dialogue
Earth	Concerned by human behavior that ignores planet's long-term interests	Biggest stakeholder in sustainability
Complex Systems Engineer	Focused on advice for systems engineers concerning what might be more effective	Emphasizes complex systems behaviors and complex systems engineering principles
Systems Thinker	Knowledgeable about complex systems, smart, and dispassionate	Provider of balanced and objective viewpoints and ideas for research
Facilitator	Concerned with fundamental issues, abstract ideas, and significant progress toward solving human made problems	Leader in posing sustainability concerns
Panel of Judges	Collective voices of intelligence and morality overseeing all thoughts and acts	Responding spirits (supreme beings, departed parents, spouse, and closest friends) to facilitator
Liberal Supporter	Concerned with human welfare and favoring government action	Voice of compassion
Conservative Advocate	Believes in individual freedom, right to life, and limited government	Naysayer
Agriculturalist	Interested in growing food production worldwide through petroleum-based fertilizers provided by fossil fuels	Optimist in solving "world hunger"

So here's the premise of this paper: We are in grave danger of ultimately producing so many people that our quality of life will nosedive and/or become intolerable because of the Earth's finite resources. If we are to deal with this dismal possibility, we must try to understand why we continue to resist facing the threat of long-term consequences in favor of emotional and sometimes irrational reactions that inhibit improving the sustainability of human life on Earth. [Ironically, in systems engineering circles these days, e.g., at the 2012 Complex Adaptive Systems (CAS) Conference in Washington, DC, and the 2012 American Society of Engineering Education (ASEE) Conference in San Antonio, TX, "sustainability" seems to be applied only to sustaining the operation of the target hardware/software system or product development and manufacturing!]

The ensuing dialogue and discussion includes data on the history of and predictions for the world's population, population growth, fertility, and birth rates. What the author feels are appropriate complex systems engineering principles are applied to establish general guidelines for meaningful action. Specific options that might help reduce population growth rates are also suggested.

OPENING DIALOGUE

Earth: Greetings everyone! As you all already realize, I'm sure, I've been around for billions of years now and clearly have a long-term perspective on all matters relating to life on this (what I consider to be my**)** planet. If I may say so, you are certainly short-timers with life expectancies much, much shorter than mine (by at least eight orders of magnitude)! So, please hear me. What I've seen humans accomplish with technological advances in the past couple hundred years is truly remarkable, especially considering the comparatively slow pace of such advances over the past few thousand years. In fact, the more recent advances in this regard seem to be ever accelerating. Although these developments benefit many, they have also been misused to considerable degrees in harming or destroying others and our environment. I fully understand the principle of survival of the fittest groups and species, not only among humans but also the plants and animals of my domain. Thus, I tolerate the loss of human life because that helps ensure balance between my human populace and resources they consume. However, I am concerned over the ever increasing demand for (and I abhor the wanton destruction of) environmental resources. At the current pace, I don't think this can be sustained indefinitely, and may even imply drastic consequences to the quality of human life within the next several hundred years. I implore you to change by: 1) increasing your long-term view by at least one order of magnitude to see beyond just the welfare of your own grandchildren; and 2) formulate and experiment with actions that will decelerate the resource consumption and help ensure a sustainable preservation of our environment for future generations.

Complex Systems Engineer: Thank you, Earth, for providing your perspective and trying to wake us from what you see as a losing path into the future. I have been trained to take a broader view of systems development in trying to solve human made problems. In particular, we complex systems engineers consciously include key stakeholders as part of the system to be created or improved. Further, we recognize that independent people cannot be controlled, only influenced. Consequently, we try to bring some humility to difficult problems and listen to others in learning how each has their own perspective, and that no one really knows the underlying

reality of any situation. These are among some complex system behaviors and complex systems engineering principles to be explored further which we think are necessary for making lasting progress in solving our most difficult problems.

Systems Thinker: I thank you both for your comments. I also take a broad view and try hard to not only see what might be missing from problem situations but also, and more importantly, ascertain what might not even be there that would be relevant to reaching a systemic solution. I look forward to commenting further, as I see the need to inject what I hope are objective remarks.

Facilitator: Many years ago I remember studying the Christian Bible, reading many philosophical books, contemplating my thoughts, and persistently questioning my parents and close friends about issues most important to me. *Panel of Judges (parents and spouse)*: Yes, you were an intellectually gifted teenager instilled with uncommon degrees of openness and honesty, perhaps to your lasting detriment. *Panel of Judges (supreme beings)*: Rejecting fogyish thoughts, you often felt superior to your seniors and contemporaries. Considering what you thought was wrong with the world, you began to subscribe to new ideas that resonated with your ambitious plans to make things better. [Here supreme beings include supernatural spirits, "higher powers", or as several major religions of the world, e.g., Christianity and Islam, espouse, the one true god, whom will be designated, God or Allah, respectively.]

Facilitator: I stumbled across the Malthusian Theory of overpopulation, believed in it then, and probably still do, although Malthus' inevitability of human ruin has since been refuted or at least challenged.

> … responded to Malthus, pointing out that the amelioration of poverty generally reduces population growth, and that food production can be increased by a variety of means in order to meet the needs of an increasing population. (Marshall 1986)

Agriculturalist: Yes, we have made great strides with increased food production. I don't see a problem in generating enough food for future populations. *Facilitator*: I also felt there were too many credulous people in the world (Russell 1950), echoing one of my heroes, H. L. Mencken (Mencken 2012). *Panel of Judges (supreme beings)*: Yes, and you arrogantly anticipated setting things straight with your own pedantic pursuits, achievements, and contributions to society, e.g., improving the quality of life through advancing technology and shaping a more intelligent world, after attending college. But then you had no specific thoughts for limiting overpopulation. (Ehrlich 1990) *Facilitator*: With hindsight, how naïve and self-engrossed I was, but what about now?!

Complex Systems Engineer: You must behave differently and **Bring a healthy dose of personal humility when trying to solve real-world problems**. [Suggested complex systems engineering principles (White and Jean 2011) are highlighted in **bold**-faced type from here on.]

> For every difficult and complicated question there is an answer that is simple, easily understood, and wrong. H. L. Mencken. (Mencken 2013)
>
> Complex adaptive systems do pretty much as they damn please. (Holland, 1995)
>
> The study of complex systems is the study of the world as it is, not as we want it to be. Brenda Zimmerman. (Zimmerman, Lindberg, and Plsek 1998)

Humility helps especially in understanding each other's definitions. No single individual can know the ultimate truth about any complex system. We must continually seek to build mutual trust and **Nurture discussions to learn how people express their concepts using different terms**. In systems engineering and other disciplines we spend too much time arguing over definitions instead of seeking to understand how each of us uses words. Only after this mutual understanding is attained and acknowledged by all can a group make real progress. We don't need to fully agree on our use of words, although this would help us accelerate progress. Since beliefs and trust evolve over time, patience may be rewarded.

POPULATION GROWTH FACTS

Earth: I'll establish some facts about my world's population growth. At 7 billion people in 2012:

> It's getting crowded here. … in the beginning of the 20th century the entire world population was less than 2 billion people. … in 2012, the current world population … exceeded 7 billions (7,055,000,000). The world's population [was] growing by 200,000 people a day!, but [both] death and birth rates have declined over the past several decades. (World Bank) (Population 2012)

Facilitator: Yes, and some interesting facts catch my attention regarding specific countries. China is first with 1,347 billion people. India is second with 1,241 billion, and the U.S. is third with only 312 million people (Population 2012)

> The average annual percent change in the population, [results] from a surplus (or deficit) of births over deaths and the balance of migrants entering and leaving a country. … (Factbook1 2012)
>
> Of the three most populous countries, the 2012 estimated population growth rates of China, India, and the U.S. are 0.481%, 1.31%, and 0.899%, respectively; the world's is 1.10%, … (Factbook1 2012)

Despite the hope associated with some of these more reasonable growth numbers, I am still quite worried about overpopulation and the increasing numbers of people surrounding me over my lifetime. How often are urbanites, like me, frustrated with too many people!? Need evidence? Just witness heavy traffic and jams on deteriorating highways, the many illegal high-speed or lane-changing drivers, long queues at airport security check-ins, Starbucks ☹ and other coffee houses and fast-food restaurants, markets, and stores. *Panel of Judges (spouse)*: Instead of just complaining, why don't you try to do something about it? You might start by becoming more tolerant and increasing your patience and understanding of others. *Systems Thinker*: Also, it is well to note other factors (White 2012), as Paul Ehrlich has stated

> The main population problem is in wealthy countries. There are, in fact, too many rich people. The amount of resources each person consumes, and the damage done by the technologies used to supply them, need to be taken as much into account as the size of the population. (Ehrlich 1994)

Systems Thinker: A preponderance of venerable evidence relating overpopulation and consumption exists.

> Climate change and global pollution cannot be adequately tackled without addressing the neglected issue of the world's booming population, … "It is a bombshell of a topic, with profound and emotive issues of ethics, morality, equity and practicability," …"So controversial is the subject that it has become … rarely visible in public, or even in private. … it would require the natural resources equivalent to four more Planet Earths to sustain the [United Nations] projected 2050 population of nine billion people. … . We need to think about climate changers – human beings and their numbers – as well as climate change." Some environmentalists have … suggested that the planet can sustain a population of nine billion people or even more [if] everyone adopts a less energy-intensive lifestyle based on renewable sources of energy rather than fossil fuels. But … "We urgently need to stabilise and reduce human numbers. [Otherwise] unacceptable damage to the planet and a great deal of human misery [will result]." … About one in every three people alive today is under the age of 20, which means that the population will continue to grow ... . (Connor 2006)

Liberal Supporter: Agreed! In addition, people generally give no thought to the fact that they are contributing to the long-term environmental problem when driving because of their vehicles' exhaust emissions, for example. (Aldhous 2012) *Conservative Advocate*: I don't agree with the doom-sayers! The "science" supporting global warming is still seriously in doubt by many awaiting real proof – even some scientists. *Facilitator*: Nevertheless, it seems prudent to pursue reasonable opportunities that we can recognize and agree upon that should help mitigate whatever dangers might present themselves over the long term.

Complex Systems Engineer: Yes, a different systems engineering approach is required, e.g., **Pursue opportunity as well as risk management**. Instead of emphasizing preventative measures that often do not work because they do not always address root causes, focus on broader opportunities that may harbour more promise in limiting future populations. (White 2011) *Agriculturalist*: Yes, the past opportunities afforded us by the use of fossil-based materials have greatly increased worldwide food production. This can continue provided we are left alone to serve the markets of increasing population. *Liberal Supporter*: The free market cannot solve world hunger without government help, for example, in efficiently and economically distributing food where it is desperately needed. *Conservative Advocate*: But government should not interfere with free markets! That would make the food market highly constrained, not free. *Agriculturalist*: Yes, and let's not be so quick to pursue non-fossil fuels and renewable energy sources, as some governments, e.g., the U.S., are advocating! *Conservative Advocate*: Increased food production is only one way tax breaks for oil companies is beneficial.

Facilitator: I suggest that instead of focusing on a preventative measure like increased food production to save starving people, we get back to addressing the root cause, overpopulation. After population growth rate, fertility rate is the next most meaningful, and birth rate the least. A population's total fertility rate is

> the average number of children that would be born per woman if all women lived to the end of their childbearing years and bore children according to a given fertility rate at each age. The total fertility rate (TFR) is a more direct measure of the level of fertility than the crude birth rate, since it refers to births per woman. … A rate of two children per woman is considered the replacement rate for a population, resulting in relative stability in terms of total numbers. Rates above two children indicate populations growing in size and whose median age is declining. … Rates below two children indicate populations decreasing in size and growing older. Global fertility rates are in general decline and this trend is most pronounced in industrialized countries, especially Western Europe, where populations are projected to decline dramatically over the next 50 years. (Factbook2 2012).

Earth: Zero global population growth is an achievable and desired objective! *Systems Thinker*: Only for the long-term, though, considering the reality of people's live-for-today mentality. *Facilitator*: Of the most populous countries, the estimated TFRs of China, India, and the U.S. are 1.55, 2.58, and 2.06, respectively. (Factbook3 2012) *Systems Thinker*: The grave danger of unsustainability in our Earth's resources caused by overpopulation has been addressed very well by Thomas L. Friedman (Friedman 2011) (Friedman 2008), Peter M. Senge, (Senge et al. 2008), and the (late) Donella (Dana) and Dennis Meadows. (Meadows et al. 2004) These works must be read by forward thinking advocates of unbounded population increases. Their perusal will likely dull the bullishness of having such a mindset. James Case has also provided thoughts that should disturb us regarding sustainability and other topics here relevant.

> System dynamics [(Forrester 1971)] is well known to environmental and ecological economists, who use it to explore the effects of proposed policy changes and to explain in words and pictures how the phase implementation of a particular option will play out over time. The usual goal of such investigations is sustainability – for [certain animal, fish, and natural resources]. Herman Daly finds it amusing that there is now a fight to control the meaning of the word "sustainability." (Day 1996) No sooner had activists like Rachel Carson and the *Limits to Growth* authors [(Meadows et al. 1972)] managed to stir up public awareness of impending threats to the ecosystem than business interests began to introduce oxymorons like "sustainable growth" into the dialogue. In Daly's opinion, the human race possesses but a single asset – the planet we live on – and our fate depends on the magnitude of the return we are able to coax from that (fixed) asset. … Daly argues that if sustainable development is to mean anything at all, it must mean that the economy is but a part of the earth's materially closed ecosystem. Hence mankind must abandon the ideal of eternal economic growth. We must learn instead to become healthier and happier in ways that do not entail indefinite expansion. [(White 2012)] (Case 2007, pp. 253-4)

Complex Systems Engineer: We must **Balance competing interests across the system instead of trying to optimize any of its components**. There is room for a diversity of opinions and actions that can benefit the short term desires as well as deal with the long term objectives. **Utilize trans-disciplinary techniques of philosophy** (Boardman and Sauser 2008)**, psychology, sociology, organizational change theory, etc**. This principle is rooted in the Medici effect where a confluence of diverse disciplines often leads to innovation. (Johansson 2004) **Foster interpersonal and inter-organizational trust by sharing information with honesty and integrity**. We should be able to work together in making progress for the long-term on this critical problem. *Systems Thinker*: And please, train yourself to think about the possible future unintended consequences that might result from present decisions [paraphrasing Peter Drucker (Welter and Egmon 2006)].

OVERPOPULATION

Facilitator: Let us delve a little deeper into the unsustainability theme. Overpopulation is an old concern (Ehrlich 1968) but is becoming more acute in acknowledging the Earth's limited and depleting resources (Hymas 2011) (Aintablian 2011), global warming, over fishing, poaching [The wanton killing of elephants for ivory is accelerating the evolution of elephants with either greatly atrophied or even no tusks. (Selection 2011)], and intentional deforestation. [As to forests, more than half the loss of the world's natural forests (through business exploitation) has occurred since 1950. (Meadows et al. 2004, p. 75) This is another critical area that needs to be addressed in order to save the planet because trees absorb carbon dioxide and emit oxygen.]

> … population and capital systems … [perpetuate] poverty, population growth, and the tendency of the world system to overshoot its limits. … "The rich get richer and the poor get children." [Humans should not procreate in hoards like insects that lead short lives of in-adaptation to threats and disasters; humans are capable of surviving a relatively long time through adaptation in applying our remarkable brains.] (Meadows, et al. 2004, pp. 44-45) People are not hungry because there is too little food to buy; they are hungry because they cannot afford to buy food. (Meadows et al. 2004, p. 66)

Agriculturalist: And we aim to provide so much food it will be affordable to all! *Systems Thinker:* Concerning women and childbearing trends, there is recent evidence that fertility rates are dropping significantly in Latin America, primarily because women are increasingly entering the workplace and migrating to cities. (Forero 2012) *Systems Thinker*: Therefore, we need to give women at least as much economic opportunity as men! Many women should be able to take advantage of the increasing potential for online learning leading to good jobs without having to go to college. (Carr 2012) Several examples of potential problems with overpopulation follow.

Facilitator: Keep Every Human Life Sacred. Indoctrination since childhood, through religion and other beliefs, about the sanctity of every human life is common. Unfortunately, from the perspective of a long-term overpopulation threat, we have managed to evolve a culture where nearly everyone mourns death and supports

every attempt to save or prolong every human life. *Panel of Judges (supreme beings)*: How dare you say unfortunately!? Don't you know we advocate the sanctification of every human life? *Facilitator*: But is that not potentially detrimental to our quality of life? *Earth*: This sanctity also contradicts the prevalent laws of nature (as well as an aforementioned important principle of complex systems) which tend to balance life and death among both animals and plants. Don't these rules apply to humans, as well? *Conservative Advocate*: God made us special and above the animals. *Liberal Supporter*: I agree. We must endeavor to rise above nature's immorality and help carry out God's will. *Earth*: I resent you suggesting I'm immoral. You humans artificially value (based largely on myths of your religions) and nurture human life above all other life forms; how is this fair to them? *Conservative Advocate*: The world is not fair. We have thumbs and bigger brains. We have the right to exploit nature for our own ends. The profit motive trumps everything except the innate human belief in a superior being, namely God. *Panel of Judges (supreme beings)*: Thank you!

Facilitator: Save Lives No Matter What the Cost. This mindset also hastens unsustainability. Reallocating many of the resources that often prove ultimately insufficient to save some lives can be used to improve the quality of life for others. *Liberal Supporter*: But there are many examples of how people dedicate themselves to prolonging life (and thus indirectly causing population growth). We approve those intentions for ethical, emotional, and rational reasons, and we must continue to concern ourselves with the sustainability of future human life, i.e., the unborn. At the same time, we must recognize that we cannot criticize all well-meaning people from wanting to do what they can for those that need serious help. *Systems Thinker*: There's no way most people will embrace a philosophy that hinders extreme measures to help prolong their family, relatives and friends lives. But let us all agree to try enlightening the world about the potential problems of overpopulation.

Liberal Supporter: Provide Food and Water for All Starving People in Africa. Isn't this a moral imperative of Western cultures? *Agriculturalist*: Yes, and with continued advances in food and water technologies along with a pro-active alignment of the political wills within more developed countries, this can be done! *Conservative Advocate*: But many people in the world have a woefully substandard of living compared to Western countries; *vive la difference!* If instead we taught them "how to fish" and make a profit, that will all change. It is Maslov's hierarchy personified; countries that possess natural resources, a prosperous economic system, the capacity to innovate, invent, pursue the arts, and generally expand and increase the complexity of their cultures, flourish. Poor countries are too busy just trying to survive, with polluted water, not enough nutritious food, and horrible dictators that sap the country's natural resources, exploit the population, and murder those in disfavor. *C'est la vie!*

Liberal Supporter: Ignore Greater Water Shortages. Still it seems to me that solving the world's shortage of fresh water is critical. [Many people think that desalinization will solve this problem. However, this purification process will probably remain too expensive to greatly widen its scope of application in the foreseeable future.] But maybe we'll be okay if the world's population stabilizes soon; or is that just wishful thinking?

> One billion people [in the developing world] still lack access to safe drinking water. Half the human population does not have basic sanitation facilities. (Meadows et al. 2004, p. 71) Pumping up groundwater faster than it can be recharged is unsustainable. … . (Meadows et al. 2004, pp. 71-72) … In the developing countries one of every three children is malnourished. … Roughly nine million people die every year of causes related to hunger. That comes to an average of 25,000 deaths a day. (Meadows et al. 2004, p. 58)

Conservative Advocate: Why is all this so bad?! Doesn't that help alleviate an overpopulation problem? *Facilitator*: I agree. Alternatively, instead of just "washing our hands", cannot we do better in discouraging so many unfortunate births by helping to improve local economies and women's rights in such disadvantaged countries!?

Facilitator: Lament Loss of Life in Natural (and Other) Disasters. When hurricanes, earthquakes, tsunamis, and other natural disasters occur, we are appalled at the loss of human life and try to do something about preventing such future disasters. (McKenna 2011) In addition, we berate nature as to how cruel and impartial she is sometimes. Ironically, we rarely blame God or Allah, for example, although many religious people feel that "he" is in control of everything. Some Christians disagree with that and believe God does not determine everything; it is up to us to exercise "free will", as with Adam and Eve of the Bible. *Panel of Judges (parents)*: As we tried to teach you as a youth, God, in his present dispensation, is displaying the graciousness of his character and acting in secret. *Panel of Judges (supreme beings)*: Don't be so sure of that! *Facilitator*: But if God is not involved, this must be viewed as a manifestation of the balancing forces of nature previously discussed. The implication of these events not happening is dire. Just think of how many more people would be

on Earth if natural disasters, wars, and other devastating mishaps and acts of violence never occurred! Results of simple calculations provided in Table 2 support this point. [Contact the author for the algorithm employed, if desired.] Consider a situation where 10,000 people lost in a natural disaster all survive. Or conversely, assume the disaster does not occur. Then what happens to that population subset? Let's assume, hypothetically, that one generation equals 25 years and no one lives beyond 75 years. Then referring to the sixth column from the left of Table 2, note the population increase for a birth rate of 1.3 applied to each survivor [Depending on the nature of the hypothetical catastrophe, many pairs of the initial survivors may have been couples, so a birth rate of 1.0 means each such couple would have exactly two (additional) children. Many others may have been sole survivors in the sense that their partner, if they had one, was not in the survivor group. This birth rate means that a sole survivor would have just one (additional) child with someone outside the survivor group.] and their future progeny, and a death rate of 10% for all left alive during any generation. [Clearly, birth and death rates change over time, particularly over many generations. However, they are kept fixed in these hypothetical examples just to show average trends. A more elaborate and realistic model would be based on TFR but the present model is sufficient to make the point.] The increase from this iterative perturbation is about 112,000 people in 150 years (6 generations), more than 300,000 people in 250 years (10 generations), and more than 4 million people in 500 years (20 generations)! [If you think this is long term, try perusing articles in a Special Issue of *New Scientist* magazine which discuss tens to a hundred thousand years from now! (Future 2012) Higher birth rates produce even more prolific results, still terrifying even if the death rate is increased (as in the seventh and ninth columns). By using the same algorithm, assumptions, and death rate of 10%,, with a birth rate of 1.0 or less, it is apparent that the resulting population initially increases but eventually and gradually drops to zero over a certain number of generations (as in the second and third columns). This argues strongly for lower than 1.0 birth rates! *Systems Thinker*: So it is sobering but true that if such events ceased to occur humanity would be in an even deeper sustainability crisis of life on Earth! ☹

Table 1. Population growth from only 10,000 survivors

Years	**Resulting Population Increases**								
Birth Rate:	**0.5**	**1.0**	**1.1**	**1.2**	**1.3**	**1.3**	**1.5**	**1.5**	**2.0**
Death Rate:	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.1**	**0.2**	**0.1**
25	*13,500*	*18,000*	*18,900*	*19,800*	*20,700*	*18,400*	*22,500*	*20,000*	*27,000*
50	*14,350*	*25,100*	*27,790*	*30,660*	*33,710*	*27,720*	*40,350*	*33,400*	*60,100*
75	*13,965*	*31,390*	*36,759*	*42,882*	*49,813*	*38,556*	*66,315*	*52,220*	*125,490*
100	*13,044*	*36,951*	*45,896*	*56,819*	*70,018*	*51,619*	*104,534*	*79,426*	*255,541*
125	*4,637*	*34,566*	*48,000*	*65,598*	*88,338*	*62,661*	*153,915*	*114,296*	*507,697*
150	*572*	*32,319*	*50,454*	*76,271*	***112,293***	*77,385*	*228,126*	*166,969*	*1,012,147*
200	*0*	*28,188*	*56,495*	*104,835*	*184,317*	*122,323*	*506,841*	*365,467*	*4,039,335*
250	*0*	*24,461*	*64,232*	*146,413*	***306,506***	*199,161*	*1,134,462*	*813,065*	*16,148,706*
300	*0*	*21,062*	*73,938*	*206,649*	*513,386*	*329,588*	*2,547,022*	*1,820,785*	*64,586,687*
400	*0*	*15,012*	*100,739*	*419,249*	*1,454,960*	*923,736*	*12,877,732*	*9,191,295*	*1,033,348,683*
500	*0*	*9,667*	*140,807*	*861,065*	***4,145,318***	*2,621,578*	*65,178,460*	*46,505,714*	*16,533,543,470*

Facilitator: Hype Impossible Rescue Attempts. How often have we been watching television and seen a breaking news story about the attempted rescue of some poor soul(s)? It is only natural for us to feel compassion and hope the rescue is successful, while thanking our lucky stars that it is not happening to us. This bolsters our psychological tendency to want to save every human life no matter what the consequence. *Liberal Supporter*: Of course! We all need to be compassionate and do everything we can. How else could we live with ourselves?

Facilitator: Pay More for Doctors' Futile Test and Treatment Recommendations. All patients (or their insurers) are billed more when doctors order expensive tests and treatments. There is little monetary reward for making patients well through more personalized attention to each patient's overall long-term health, and promotion of general health maintenance and education. (Johnson 2010) Drug maintenance can be monetized, while healing cannot. Sustaining life through medicine, tests, and treatment is an insidious business model practiced in civilized industrial nations. In addition, a majority of patients in troubled health states trust their doctors too much, fatalistically accepting grim diagnoses that are based on average statistics and the physicians' imperfect knowledge. Instead people need to be more mindful of the possibilities for getting and staying well or at least lengthening a happier life which can be tailored to their unique situations. (Langer 2009) (Hawn 2011)

Complex Systems Engineer: Every patient, thinking of themselves as a complex system, should help to engineer their health from the inside: **Follow a holistic approach focused on the entire system and the**

relationships: a) between the system and its environment; and b) internal interactions. Again, all those directly concerned with a patient's health must look at the big picture and strive for balance, common sense, and a positive attitude. (Siegel 1990)

Liberal Supporter: Pursue Voluntary Charitable Initiatives. One wonders why, if these initiatives are so important to humanity, we do not devote even more resources to enhance these ostensibly worthwhile efforts!? Does the answer have a lot to do with what appears to be misguided societal priorities? Do those with power and money, like our *Conservative Advocate*, not really care enough about saving every human life!? *Conservative Advocate*: Hey, give me a break! *Systems Thinker*: By mutual understanding, reining in our emotions, building trust, and rethinking creatively, we can address these problems more effectively.

SOCIETAL GOALS

Facilitator: If we establish the long-term objective of limiting future population growth, we can work backward as well as forward while ensuring progress toward lengthening lives. Moreover, we really don't need to migrate to another planet, particularly, if we can eventually mine precious resources to sustain life on Earth – motivated by profit!?

> [Liz Else:] What sort of things shouldn't we do? [E. O. Wilson:] Continue to put people into space with the idea that this is the destiny of humanity. It makes little sense to continue exploration by sending live astronauts to the moon, and much less to mars and beyond. It will be far cheaper, and entail no risk to human life, to explore space with robots. It is a commonly stated idea that we can have other planets to live on once we have used this one up. That is nonsense. We can find what we need right here on this planet … if we take good care of it. (Else 2012)

Complex Systems Engineer: I agree, and three principles of complex systems engineering apply here. **Stimulate a system of self-adaptation and self-organization to enable, evolve, and accommodate change through competition and collaboration**. Further, those who can take charge must **Create environments (as a governor, leader, or manager) for interactions of all system elements**. Supporters must **Formulate heuristics (rules of thumb) and educate emotions** (Brooks 2011) **to assist decision makers**. *System Thinker*: However, this phenomenon of complex system interactions expressed in the second principle just above is only beneficial up to some limit of material support beyond which we may "overshoot". Thus, we need to restrict population to levels that can be matched by available natural resources.

WHAT CAN BE DONE?

Facilitator: I'm sure we'll have difficulty in all agreeing on what to do. Nevertheless, I feel that we must abandon our ingrained mindset to vigorously propagate all human life without bound no matter what. Fundamentally, our incentives need changing to improve the quality of life of all humankind while conserving the Earth's resources.

Complex Systems Engineer: Yes, and what would help greatly is to embrace two other complex systems engineering principles **Design, formulate, and certify simple elements**. This principle, which is intended to shun complicated solutions that may satisfy very few, can be invoked by concentrating on life qualities that nearly everyone cares about such as safety, independence, opportunity, freedom, and happiness. Regarding social networks and interrelationships among people, another principle is a propos. **Develop open, layered architectures well-matched to networks of tightly-coupled, highly-interactive elements within each sub-network, and "loose" inter-connections among the sub-networks**. This will help ensure that like-minded interdependent people can thrive within their groups while staying in touch and peacefully co-existing with other groups with which they have less in common. *Systems Thinker:* Clearly, we must do more: 1) scientifically to better understand overshoot and overpopulation's effect on sustainability; and 2) complex-systems-engineering-wise to assess prospects for coping and navigating toward an optimistic future. *Liberal Supporter*: As a start why don't we try to create and adopt a list of creative incentives for limiting overpopulation? *Facilitator*: I have several ideas, and you may have some also.

Facilitator: Increase Social Status for Increasing One's Quality of Life. Let's make online education more respectable as an alternative to college. *Liberal Supporter*: We could also encourage aid to universities to: 1) help families reduce the interest rate burden on college students' loans; and 2) benefit graduates that have achieved advanced degrees, deservedly, with Federal or State Government subsidies, grants and charitable bequeaths. *Systems Thinker*: Interest rates are at record lows. Why not marry college loan rates to the small federal funds rate that banks pay? *Conservative Advocate*: I'm in favor of maintaining but not reducing the

present college loan rates, and I wouldn't be too interested in hiring online learners for that matter. Actually, I'm more intrigued at the prospects of using more robotic workers.

> A team of robots endowed with the hand-eye coordination required for such recreation [viz., baseball] could operate any factory in the world better and more cheaply than the most skilled and dedicated human workforce. Until it crosses that divide, automation will remain a work in progress. … Automation tends to attach and "hollow out" the middle of the income distribution, where the greatest potential savings lie[s]. Automation isn't the main culprit just now, because foreign workers are still cheaper than robots. But someday that will change and will bring the outsourcing bandwagon to a screeching halt. … The steady advance of automation will only make it harder for the average citizen to make the cut separating members of the workforce from the hard-core unemployed, of whom there will be increasingly many. At present, even some of those who do make it into the full-time workforce – the so-called working poor – find it impossible to subsist on the wages they earn. (Case 2007, pp. 306-7)

Liberal Supporter: I find this prospect frightening in terms of its potential for decreasing the quality of life of the middle class! *System Thinker*: Stepping back and looking at the bigger picture again, we must become more concerned with reducing demands for more children through highlighting concomitant quality of life improvements.

Liberal Supporter: Create Better Economic Opportunities So Poor People Have Fewer Children. Improvements in education and productive capabilities would result in lower TFRs. *Conservative Advocate*: This is okay if the incentives come from private initiatives, such as school vouchers, and not from the Federal Government.

Facilitator: Re-Educate Families, Not Just the Children. Again, online education should be a component of such an effort. *Systems Thinker*: More extensive and effective worldwide education will be the best answer to overpopulation. *Conservative Advocate*: But the U.S. must not pay for that. Moreover, we must drastically cut the exorbitant federal educational spending and eliminate the wasteful and ineffective Department of Education. Instead, we must allocate federal funds to the states, local communities, and parents where it would do the most for students at much lower cost to taxpayers. Furthermore, profits do not come from book learning. Business success often accrues to those with a talent for seeing opportunities to create value for consumers.

> … Many college graduates already recognize that their degrees aren't really needed for the work they do, and they suspect that time will continue to erode the commercial value of such degrees. … Charles Murray, co-author of *The Bell Curve* [(Murray and Herrnstein 1994)], has long maintained that the United States spends too much of its education budget on the least gifted and least motivated students, … and too little on those with the talent and inclination to do so. (Case 2007, p. 314)

Facilitator: I'm getting frustrated; why would anyone want more people?!

> In time, the ruling elites will again overplay their hand. The mounting federal deficits, massive trade imbalances, global warming, environmental degradation, impending energy shortage, loss of arable land, and uncontrolled population growth are all unsustainable. (Case 2007, p. 317)

Conservative Advocate: Those with money are entitled to rule but they are not at fault – it's the Federal Government; and, again, I don't accept manmade global warming.

Facilitator: Revamp Healthcare for Wellness Not Sick Care. *Liberal Supporter*: Improve people's quality of life by motivating wellness (e.g., through tax breaks) and raising the quality of health care before people become ill. *Systems Thinker*: If there are fewer patients because of general wellness and constructive limits in population growth, those in trouble health-wise will receive care that is more effective and affordable. *Facilitator*: I like the idea of promoting peoples' health (maybe they can live into their 100s with continuing medical miracles). However, this will be impossible unless we solve the overpopulation problem.

Liberal Supporter: Improve Sanitary Conditions to Prevent Diseases Which Drain Health Care Resources. Cleaning up the environment would reduce the pressure on having more children to make up for those that die of the associated diseases. *Conservative Advocate*: Yes, maybe that's one of the few solely Federal Government functions that makes sense; why should the private sector be forced to pay for that?

Facilitator: Incentivize Birth Control. In contrast to current tax breaks for more children, people having children might be assessed greater fees – one-time fees at birth or annual fees as kids grow up – or both. Nevertheless, such incentives or disincentives would exacerbate the abortion debate because the pressure to abort would increase. Yet, measures to prevent pregnancy might become more viable. *Systems Thinker*: If the world's population reaches untenable proportions, governments might introduce a voluntary subsidized policy of widespread sterilization of males and/or females, not for attacking "undesirable" races, to be sure, but for

significantly retarding human population growth to save the planet. (Nicholls 2011) *Liberal Supporter*: That will be the day! Anything to survive, correct!?

Facilitator: Provide More Benefits to Families with Fewer Children Instead of the Reverse. Give those that have fewer than the current average number of children a tax break every year. *Liberal Supporter*: I do not support that! We love our kids, so the more the merrier! *Conservative Advocate*: I am for more tax breaks but aborting more babies is a show stopper!

Liberal Supporter: Incentivize Many More Adoptions of Unwanted Children. Make it easier and less expensive for adoptive parents. Let us campaign for greater societal acceptance of adoption, especially for those that involve mixed-race families. Subsidize (tax breaks?) adoptive parent(s) not only during the adoption process but also throughout the rearing of their adoptive children. *Systems Thinker*: This would be a great way of "absorbing" some of the future excess populace. *Conservative Advocate*: But again, who foots the bill?

Earth: Convince the Public and Re-Orient the Politicians. Many controlling or influential leaders would have to act in their countries and the world's best long-term interests. The media would also have to help much more in curtailing their hype of short-term sensationalism and instead devoting serious attention to the long term. *Panel of Judges (supreme beings, spouse, and closest friends)*: Dream on! History has shown that most in power don't care to project much beyond their own life spans except for their personal legacies.

Complex Systems Engineer: Here, in seeking improvements, we must apply a final principle of complex systems engineering. **Consider political (P), operational (O), economic (E), as well as [technology] (T) factors**. If you feel the potential solutions noted above are more in the realm political programs, think again. Politics is arguably the most important POET component of complex systems engineering!

CONCLUSION

Systems Thinker: The evidence concerning the sustainability of our Earth's resources suggests a very serious overpopulation problem in our future.

Complex Systems Engineer: I, for one, take this seriously and have suggested some complex systems engineering principles that might help guide our future actions. *Facilitator*: Yes, let us become more sensitive to population growth and try to conceive of and experiment with reducing future growth rates; I have suggested several possible actions. *Liberal Supporter*: So have I. *Earth*: Thanks to each of you! *Conservative Advocate* and *Agriculturalist*: We remain unconvinced and think you are all exaggerating. *Panel of Judges*: The Facilitator has attempted to call people's attention to a world at risk due to population growth and various potential mitigations of those risks. Realistically, though, we don't think there's much hope in changing people's mindsets and behaviors sufficiently to adopt a long-term plan of course corrections. *Facilitator*: But we can try to change our mindsets to more flexible "mindsights" (Hawn 2011, p. xiv) considering several admonitions: "There are three types of people in the world: those that make things happen, those that watch things happen, and those that wonder what happened." (Blake 2011) "You miss 100% of the shots you don't take." (Gretzky 2012) "When you do something, do it with the total dedication of your abilities, do it with loving honesty in your heart to make the world a better place, and do it now." (Randon 2012)

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