

**Guided Study Program in System Dynamics**  
System Dynamics in Education Project  
System Dynamics Group  
MIT Sloan School of Management<sup>1</sup>

Assignment #13

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**Reading Assignment:**

- *Beyond the Limits*,<sup>3</sup> by Donella H. Meadows, Dennis L. Meadows, and Jorgen Randers

Please refer to Road Maps 5: A Guide to Learning System Dynamics (D-4505-4) for an introduction to *Beyond the Limits*.

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<sup>3</sup> Meadows, Donella H., Dennis Meadows, and Jorgen Randers, 1992. *Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future*, Post Mills, VT: Chelsea Green Publ. Co., 300 pp.

## **Exercises:**

Please keep the questions for each chapter in mind as you read the chapter. They are designed to focus your reading, explore some of the ideas brought up in the reading, and relate them to ideas studied so far. Answer as many questions as you can and have time for, but we recommend that you submit an answer to at least one question from each chapter.

### Chapter 1: Overshoot

A. Based on your experience with the CFC modeling exercise from assignment 7, discuss the behavior driving the growth of carbon dioxide concentration in the atmosphere as shown in Figure 1-3.

B. Refer to table 1-1 on page 7. Can you identify any causal relationships between any of the activities and products? Are these relationships reflected in the growth rates over the 20-year range? Which areas have grown fastest or slowest and why? What do you expect for the next 20 years?

### Chapter 2: The Driving Force: Exponential Growth

A. Look at Figure 2-2 on page 16. Using the doubling-time calculation method, estimate the annual population growth fraction.

B. Using figure 2-5 and your graphical integration skills, describe the behavior of the population stocks for more and less industrialized nations from 1900 to 2100.

C. On page 35, the authors include a feedback diagram for the stock of industrial capital. What types of behavior is the feedback system likely to generate? Why?

### Chapter 3: The Limits: Sources and Sinks

A. Give five examples of planetary sources and five examples of planetary sinks.

B. World Bank economist Herman Daly explains that for a renewable resource, the sustainable rate of use can be no greater than the rate of regeneration. Provide an example of a system that uses a renewable resource at a sustainable rate. Then, thinking back to the deforestation model from assignment 3, comment on the effect of delays on the system.

C. Grain yields could be much higher in industrializing countries. Why do you think that they are so low? What could be done to improve them?

D. What policies can poor countries with hostile neighbors adopt to avoid reaching their water limit?

E. What are some ways a country can prevent overharvesting in other, sovereign countries? For example, how would a country like Belgium prevent overharvesting in Brazil?

F. Discuss the differences between manufacturing redesign and end-of-pump clean-up.

G. Discuss the differences between a program that increases recycling and a program that increases the lifetime of products.

#### Chapter 4: The Dynamics of Growth in a Finite World

A. Figure 4-8 on page 123 shows the four possible behavior modes of the World model and describes their structural causes. For each behavior mode, describe, in a few sentences, the simplest model that could produce such behavior. Include information about the number of stocks in each model, the relationships between the stocks (if more than one) and their flows, and the shape of possible table functions (you should justify their use). You do not need to submit any models or behavior runs, just describe the structure, and explain how and why it would produce the behavior mode.

B. Figure 4-8 mentions that one of the structural causes of the “overshoot and oscillation” and “overshoot and collapse” behavior modes is that signals or responses are delayed. Explain how you would incorporate a delayed signal or response into the structure of a model. Explain how and why this would cause a delay.

C. Describe a simple example of a system (not necessarily related to any of the topics discussed in “Beyond the Limits”) that could exhibit overshoot and oscillation.

D. Describe a simple example of a system (not necessarily related to any of the topics discussed in “Beyond the Limits”) that could exhibit overshoot and collapse.

#### Chapter 5: Back from Beyond the Limits: The Ozone Story

A. Think back to the model of CFC releases from assignment 7. How would you expand that model to study the actual effects of CFCs on the destruction of ozone? You may choose whether you would like to submit a model or provide a verbal description; in either case, make sure to explain your reasoning.

B. On page 152, the authors state that “NASA scientists found that their computers had been programmed to reject very low ozone readings on the assumption that such low readings must indicate instrument error.” Can you think of any examples of similar attempts to ignore the actual behavior of a system?

Chapter 6: Technology, Markets, and Overshoot

A. Chapter 6 essentially shows that technology and current “efficient” market systems cannot be relied upon to solve the problem of the limits to growth. A section in an undergraduate microeconomics textbook by Robert S. Pindyck and Daniel L. Rubinfeld,<sup>4</sup> however, says:

“The early 1970’s was a period of public concern about the earth’s natural resources. Groups like the Club of Rome predicted that our energy and mineral resources would soon be depleted, so that prices would skyrocket and bring an end to economic growth. But these predictions ignored basic microeconomics. The earth does indeed have only a finite amount of minerals, such as copper, iron and coal. Yet, during the past century, the prices of these and most other minerals have declined or remained roughly constant. [For example, our annual steel consumption is about twenty times greater than it was in 1880. The price of steel, however, has remained almost constant over that time period].”

Discuss some of the reasons why the price of steel may not have increased over the past century.

B. The microeconomics textbook continues two paragraphs later:

“This is not to say that the prices of copper, iron and coal will decline or remain constant forever—these resources are finite. But as their prices begin to rise, consumption will likely shift at least in part to substitute materials.”

Rising prices will certainly increase the pressure to find substitute resources. What are some potential problems in waiting for prices to give the signal to develop and implement the substitutes? Think about the current state of corporate competition and market attitudes.

C. It would be better for society as a whole if individuals realized the need to find renewable substitutes *before* prices started rising. What are the incentives for a person or organization to develop such substitutes much before they are urgently required? Consider various price, material quality and ease of substitution effects.

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<sup>4</sup> Pindyck, Robert S. and Daniel L. Rubinfeld, 1992. *Microeconomics*. New York, NY: Macmillan Publishing Company, 720 pp.

Chapter 7: Transitions to a Sustainable System

A. The simulation runs of the World3 model demonstrate that as long as we do not change the fundamental way in which we use resources, we are not removing the limits, but simply delaying their effects. The more we use technology today to push back the limits to growth, the worse the effects will be in the future. Refer back to the systems notes in the appendix of *Systems 1, An Introduction to Systems Thinking* by Draper L. Kauffman. Which systems notes best describe the lessons gathered from the World3 model? Can you think of any examples of similar systems from your personal experience?

B. The authors recommend steps that must be taken in order to transition to a sustainable system. The first two recommendations are to improve the signals and speed up response times. How would those recommendations be implemented in the real world? For example, which people, governmental agencies, or private organizations would be equipped to carry out these tasks?

C. How do the value and incentive systems in our current social systems need to change to make the solutions in the book viable?

D. The authors say that poverty, and unemployment must be eliminated before we can reach a sustainable equilibrium. Keeping in mind Professor Forrester's paper *Counterintuitive Behavior of Social Systems*, suggest some ways of dealing with these problems in the short and long-term.

Chapter 8: Overshoot but not Collapse

A. Chapter 8 discusses the agricultural and industrial revolutions. What do you think of the so-called technological revolution? How does it fit into this discussion?

B. Discuss the quote by Ralph Waldo Emerson on page 225. To what extent is it still relevant today?

C. The authors list on page 225 many components of their vision for a sustainable society. Which aspects of the vision are immediately realizable? Which aspects will be the most difficult to realize?

D. In the preface to *Beyond the Limits*, the authors revised the summary conclusions from *Limits to Growth*. Do you agree with these revisions? Why or why not? What are some of the factors that have may led to these revisions?