BENG 5613 - Simulation Modeling of Biological Systems
(subtitle: Using System Dynamics to Model Continuous Systems)

Class Syllabus

<u>INTRODUCTION:</u> This syllabus begins with a series of "Special Notes" that are designed to put this course in context regarding a number of issues and situations. These are followed by a more detailed description of course content which, in a few instances, may duplicate some "Special Note" material.

Special Notes about Course Issues and Situations

	<u>SPECIAL NOTE No. 1:</u> COURSE BACKDROP, FORMAT AND OFFERINGS	***BENG 5613*** is currently scheduled to be taught (a) as an 8-week course offered in Term 1, and (b) as a full semester course offered in the Spring Semester. All offerings have the same content and use the same web-based format. The course is project-based in its approach to learning as it has been since its inception in the late 1980's. However, its nature and focus were changed in 2013 to reflect the following:
	a.	First, spreadsheets and similar software have largely replaced the use of the more "fundamental" computer languages (such as Fortran and Basic) in making calculations among relatively complex mathematical-logical relationships. Furthermore, spreadsheets have the capability of easily displaying graphics and are standard tools used by a wide range of audiences. Accordingly, Excel is used in significant part in ***BENG 5613*** as one of two simulation software programs in the course.
	b.	Second, in modern formal simulation languages, graphical objects are now often used to assist in the structuring of computer code to a much greater extent than when ***BENG 5613*** was first developed. Accordingly, the simulation language Vensim PLE (to be discussed in more detail later) is used (in addition to Excel) in order to familiarize the student with one example of these "graphical object" types of simulation languages.
	c.	Third, there is an increasing emphasis today on the issue of sustainability which requires a more holistic systems approach to modeling than was used in the earlier versions of ***BENG 5613***. This means that technology, economics and societal values all have to be considered as part of total systems analysis. Furthermore, the focus needs to be more macro-level than micro-level, often incorporating what amounts to "policy" as a key part of the "decision-making" within dynamic models. Accordingly, continuous simulation, rather than discrete simulation, is the primary modeling focus of ***BENG 5613***. (Students with a primary interest in discrete simulation will find a number of courses on this topic in the UA Industrial Engineering Department such as "*IENG 5813 – Introduction to Simulation*".)

	d.	Fourth, sustainability has become a major emphasis both nationwide and worldwide, and it certainly is considered to be of major importance within UA's Biological & Agricultural Engineering Department in that many of its course offerings are related to the sustainability of food, water and energy systems.
	e.	And fifth, the offering of ***BENG 5613*** is in a web-based distance education "8-week term" and "full semester" format. In part, this is intended to assist students in UA's MSE and OMGT programs as well those on-campus students seeking UA's Graduate Certificate in Sustainability to bridge a number of gaps between the technical aspects of sustainability and the social and economic aspects (the latter being addressed in ***BENG/OMGT 5633: Linkages Among Technology, Economics and Societal Values*** as taught each term/semester by the Instructor of ***BENG 5613***).
	SPECIAL NOTE No. 2: READING MATERIAL, SYSTEM DYNAMICS HISTORY, AND ROLE IN ANALYZING SUSTAINABILITY	***BENG 5613*** draws heavily on the reading materials provided by MITOPENCOURSEWARE (Massachusetts Institute of Technology) for its course "System Dynamics Self Study" by Professor Jay Forrester (http://ocw.mit.edu/courses/sloan-school-of-management/15-988-system-dynamics-self-study-fall-1998-spring-1999/). Professor Forrester was the primary developer of the System Dynamics approach to continuous modeling which has had a major impact on the holistic modeling of complex systems and is offered as a separate course(s) by many universities. Arguably, it is the System Dynamics approach that offers the best hope for quantifying the dynamic relationships among technology, economics and societal values that promote sustainable prosperity and well-being.
	SPECIAL NOTE No. 3: PROJECT-BASED AND TOPIC DRIVEN	***BENG 5613*** is project-based and topic-driven rather than test-based and lecture-driven. Accordingly, students should expect to do considerable independent reading (along with viewing some supporting video System Dynamics lectures and Excel/Vensim PLE template instructional videos) and to be directly involved in creating continuous System Dynamics simulation models. Towards this end, there will be one introductory modeling project ("lottery project") designed to acquaint the student first with the fundamentals of System Dynamics in general and second in using Excel and Vensim PLE. This will be followed by the systematic development of the *Community Development and Sustainability Model* (CDASM) in a 10 stage process. CDASM is designed to offer insight into interactions among a number of conflicting societal goals, especially as related to sustainability.
	SPECIAL NOTE No. 4: TOOL FOR ANALYZING SUSTAINABILITY POLICIES	BENG 5613's CDASM should be viewed as a "tool" for analyzing the long-term dynamic impacts of a range of technological, management, economic and societal decisions ("policies") on a "community system" given a set of resources. A System Dynamics model such as CDASM reflects the extent to which a set of policies and resources may be considerable sustainable, but CDASM does not offer alternatives directly.

	SPECIAL NOTE No. 5: FLEXIBILITY AND ASSIGNMENTS	Spring 2014 was the first time that ***BENG 5613*** was offered in a web-based format using CDASM as a proverbial "building block" for model development. Accordingly, modifications to the course structure and processes continue to be made to include some shifting in the timing and expectations of the assignments.
	SPECIAL NOTE No. 6: A RELATED COURSE AND SPECIAL TOPIC OPPORTUNITIES	***BENG 5613*** may be of special interest to those MSE, OMGT, BENG and other graduate students who are seeking a special problems/topics type course (such as ***OMGT 577V: Special Problems*** or ***GNEG 590V: Special Topics***) involving some aspect of modeling as related to sustainability and policy. Consider the following:
	a.	While independent in content, ***BENG 5613*** is designed to quantify the linkages and premises of the conceptual model presented in ***BENG/OMGT 5633*** (cross-listed): ***Linkages Among Technology, Economics and Societal Values***. This quantification can open the door to a wide range of opportunities.
	b.	If a student wishes to analyze a particular system of special interest to him/herself or his/her employer, one option is to use ***BENG 5613*** and ***BENG/OMGT 5633*** and a "special problems/topics" course for three purposes: (1) To receive academic credit towards the graduate degree; (2) To acquire a type of recognition for having demonstrated a certain type of professional expertise; and (3) To produce a product of theoretical and/or applied value, perhaps as related to sustainability.
	SPECIAL NOTE No. 7: KEYS TO SUCCESS.	***BENG 5613*** **is not** for everyone. Success and avoiding endless frustration require the following: 1. Considerable self-initiative. 2. A willingness to work hard. 3. Careful and timely reading and application of all the instructions. 4. Paying close attention to detail. 5. Submitting assignments on time. 6. Thinking more like a consultant than a graduate student.

Course Description

I.	**Last Updated:**	November 3, 2017
II.	**Title:**	**Simulation Modeling of Biological Systems**
III.	**Subtitle:**	*Using System Dynamics to Model Continuous Systems*

IV.	**Course No's.**	***BENG 5613*** (not cross-listed elsewhere at the present time)
V.	**Instructor:**	Otto J. Loewer [Professor in the UA Biological & Agricultural Engineering Department, PhD, PE, extensive experience in leading interdisciplinary computer modeling teams, former Dean of Engineering, member of the LSU College of Engineering Hall of Distinction.]
VI.	**Contact Information:**	
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	Office Phone:	479-575-5118
	Mobile Phone:	479-409-8182
	Email:	OJL@uark.edu
	Web address	(Old: http://wordpress.uark.edu/OJL); (New: https://exploring-linkages.uark.edu/)
VII.	**Office Hours:**	An appointment time can be arranged via email for either in-person visits or phone conversations (including Skype if necessary). Specific group times for broader discussion will be established upon consultation with those enrolled in order to accommodate everyone insofar as possible. Do not hesitate to call during any time of the week between 8:30 am and 11:00 pm with the exception of Sunday before 2:00 pm (and leave a message if I'm not available).
VIII.	**Semester/Term:**	The present plan, subject to change depending upon demand, is to offer the course two times per academic year, once as an 8-week course during Terms 1 in the fall and again as a full-semester Spring course.
IX.	**Course credit:**	3 hours
X.	**Time and Day:**	Web-based (although the full-semester version may meet occasionally and informally as needed- usually on Tuesday evening at 6:00 pm at a location to be determined).
XI.	**Place:**	NA (see "Time and Day" above)
XII.	**Course Goal:**	To enable students to develop a comprehensive systems approach for analyzing and modeling continuous dynamic systems of all types to include technological, economic and societal, especially as influenced by policies that are associated with sustainability.
XIII.	**Course Objectives:**	The specific objectives of ***BENG 5613*** are for students to develop the following skills, products and awareness:

	a.	Expertise in using the System Dynamics approach to symbolically present the dynamic relationships among various components of the system to be modeled in a manner to be readily understood by those having different backgrounds, experiences, expertise and perspectives.
	b.	Being able to use the full range of System Dynamics techniques to model dynamic continuous systems through the use of Excel.
	c.	Being able to use the full range of System Dynamics techniques to model dynamic continuous systems through the use of the Vensim PLE simulation language.
	d.	To become aware of the professional initiatives, endeavors, literature and organizations associated with System Dynamics.
	e.	To become sufficiently competent with the use of System Dynamics so as to be able to conceptualize and model dynamic continuous systems, especially those that are related to sustainability and the linkages among technology, economics and societal values.
XIV.	**Use of the word "Sustainability" in the Course:**	Today, the term "sustainability" is used to reflect a wide range of views; that is, it means very different things to different people. At one extreme, sustainability may mean basic survival of the human species. At the other extreme, sustainability may mean that the trends in increased consumption will be able to continue indefinitely and unabated. The position taken by this course is that what Society is really seeking is *"sustainable prosperity and wellbeing"*, something that has yet to be fully defined but that reflects, for the most part, an eventual level of satisfaction with life as it reveals itself over time.
XV.	**Present Situation:**	Sustainable prosperity and wellbeing are threatened in the foreseeable future because change is occurring at an increasingly fast rate. The associated complex challenges that these changes offer will be difficult to overcome without a reduction in current standards of living, especially in the developed world. Growing population and environmental pressure coupled with the need for sustainable supplies of food and energy are problematic, especially in the face of concerns about climate change. Solving progressively more complex problems will require that those of differing expertise, experiences, backgrounds and perspectives have the ability to effectively communicate a basic understanding of the linkages among technology, economics and societal values. One key component for developing this understanding is to be able to quantitatively describe these linkages through the use of comprehensive modeling techniques such as that used by System Dynamics.

XVI.	**Need for the Course:**	The course focuses indirectly on the need for Society to have enlightened leadership if sustainable prosperity and wellbeing are to be efficiently and effectively achieved. Via this course, students will gain the following critical skills needed by enlightened leaders, either directly or indirectly (through the abilities of others) to include:
	a.	Being able to examine complex entities and to divide them into their key components and causal relationships in a manner that can be readily understood by those with an interest in the system in question.
	b.	Having the ability to mathematically model the dynamic changes among these key components and relationships.
	c.	Acquiring greater communication skills through the use of these mathematical models so as to become more effective in leading various societal segments towards sustainable prosperity and wellbeing.
	d.	Providing MSE, OMGT and other graduate students a sequence of courses via this course (***BENG 5133***) and ***BENG/OMGT 5633*** (***Linkages among Technology, Economics and Societal Values***) that will allow them to develop a special topic/project graduate course such as ***OMGT 577V. Special Problems*** or ***GNEG 590V. Special Topics***) that would create a continuous simulation model of value to the public or an employer.
	e.	Provide graduate students (as applicable to the University of Arkansas Office for Sustainability and Academic Programs), the opportunity to take ***BENG 5613*** (and ***BENG/OMGT 5633: Linkages Among Technology, Economics and Societal Values***) as among the UA-approved courses for obtaining a *Graduate Certificate in Sustainability*.
XVII.	**Text:**	Note the following:
	a.	There is no required textbook for the course. Rather, the class reading will draw heavily on the material provided by MITOPENCOURSEWARE (Massachusetts Institute of Technology) for the course "System Dynamics Self Study" by Professor Jay Forrester (http://ocw.mit.edu/courses/sloan-school-of-management/15-988-system-dynamics-self-study-fall-1998-spring-1999/).
	b.	However, there are two texts that are excellent resources for students and are recommended - but not required: (a) "***Study Notes in System Dynamics***" by Michael R. Goodman (Wright-Allen Press) ISBN 0-914700-00-6; and (b) "***Introduction to Computer Simulation***" by Nancy Roberts et al. (Productivity Press, Portland, Oregon) ISBN 1-56327-052-8.
	c.	In addition to the above, there may be selected reading material, yet to be fully identified, that may require downloading from the web, and/or check out from the UA Library.

XVIII.	**Material and Expertise to be provided by the student:**	Note the following:
	a.	Students are expected to have a working knowledge of and full access to Blackboard, Excel, PowerPoint, Word, and email, preferably through a laptop.
	b.	Students will be expected to download the Vensim PLE simulation language (a free download) via http://vensim.com/free-download/ . Furthermore, students are encouraged to examine the entire Vensim website for other materials that might be of interest (http://vensim.com/).
	c.	Students should be familiar with fundamental statistical relationships (such as provided in UA courses AGST 4023 or STAT 4003 or INEG 2313).
	d.	***NOTE:*** *There is* ***no*** *prerequisite requirement that students complete a course in "discrete simulation" prior to taking this "continuous simulation" course. However, completing such a course at some point during a student's graduate program would, in combination with this course, provide a relatively complete view of the two major categories of dynamic computer simulation.*
	e.	***NOTE:*** *Students will need to have sufficient mathematical and programming expertise and* ***temperament*** *(patience and persistence) that will allow them to successfully conceptualize, develop, analyze and convert mathematical and logical relationships into and out of Excel, and with some instruction, into and out of Vensim PLE, all in a timely manner.* ***Keep in mind that the life of a programmer is often a lonely life!***
	f.	Students may come from any academic background if they have the expertise described above.
XIX.	**Class material and assignments:**	All class material, including submission of assignments, will be administered through the "content" section of Blackboard.
XX.	**Other Supporting Material used in Class:**	Assigned and supplemental material are provided via linkages from Blackboard and include but are not limited to the following:
	a.	Linkage to the MITOPENCOURSEWARE (Massachusetts Institute of Technology) for the course "System Dynamics Self Study" by Professor Jay Forrester (http://ocw.mit.edu/courses/sloan-school-of-management/15-988-system-dynamics-self-study-fall-1998-spring-1999/)
	b.	Linkage to Vensim website (http://vensim.com/)
XXI.	**Course Environment and Disclaimers:**	Note the following:

	a.	This course requires considerable self-initiative, flexibility and "one-on-one" phone and email interaction on the part of both the student and the Instructor given the nature of the course and that it is taught in the web-based format.
	b.	Blackboard will be the mechanism by which all class material will be conveyed to include emails and assignments.
	c.	It is highly likely that students will possess different levels of skills with regard to mathematics and the use of Excel and related software packages. Furthermore, these skills may, and likely will, exceed those of the Instructor at certain times and in certain situations. However, the intent is that the class environment will encourage learning from each other over the course of the term/semester.
	d.	It is important that the student view this class as being somewhat broader than simply physiological modeling of certain biological processes. Rather, System Dynamics should also be viewed as a philosophical approach where the mathematical-logical relationships are divided into comparatively simply relationships devoid of the need for high level calculus. (And as a side note, many students report that their understanding of the principles of calculus increased dramatically as a result of this course!)
	e.	At the present, it is the intent of the Instructor to: (a) Offer this course two times per academic year to include during the 8-week Term 1 (fall) and again as a full-semester course during the Spring Semester. [*While it is likely that most of the students will be engineers, the course is open to those with other backgrounds who have the expertise stated above*]; (b) Perhaps modify the current catalog description to reflect the changes in course emphasis more towards continuous simulation, especially as related to the formulation, behavior and analysis of complex macro-level systems as impacted by policy decisions on sustainability goals.
	f.	Students need to understand that modeling of discrete systems is an important area of simulation but that it will not be addressed to any extent in this course. The reasons are several to include: (a) Sustainability of large-scale systems is best modeled through macro-level continuous simulation; (b) Discrete simulation generally requires a special simulation language and is not well suited for spreadsheets; (c) There don't appear to be any courses on the UA campus that focus on the important area of System Dynamics; and (d) INEG presently offers courses that focus on discrete simulation, and ***BENG 5613*** doesn't want to duplicate this effort.
	g.	Blackboard is a great tool for the exchange of information between the students and Instructor via the web. However, there are likely to be a number of "glitches" along the way. Thus, a greater level of flexibility is to be expected from both the students and the Instructor than might be the case in a traditional "live" class.

	h.	The Instructor expects the students to conduct themselves ethically in all matters related to the offering of the course to include all acts of plagiarism. In effect, the "do right law" is in effect. (Students should ask the Instructor about the "do right law" if there is any doubt as to its history or what it implies.)
XXII.	**General Outline and Structure of Course:**	The class is structured around having 15 "class sessions" that in total constitute 3-hours of academic credit. These 15 sessions are organized as follows:
	a.	**Sessions 1-4:** Developing a simple model (called the "*Lottery Model*") intended to systematically grow the comprehensive skill set associated with System Dynamics. In addition, all of the reading assignments are to be completed during these first 4 Segments as well as four lectures, four template-focused videos and four blog entries. This part of the course will account for about one-third of the course credit.
	b.	**Sessions 5-15:** This portion of the course will be devoted primarily to systematically developing and presenting a comprehensive dynamic continuous simulation model "(*Community Development and Sustainability Model* - CDASM) (also sometimes referred to as the "sustainability model" and pronounced "cah-daz-em"). CDASM will be developed through 10 stages, each building upon prior stages and increasing in complexity and insight into the tradeoffs associated with development and sustainability. Concurrently, eleven more lectures and eleven more blog entries (one each per session) are assigned. Furthermore, the last Session will be devoted to a written final report that covers all the material in the course. Sessions 5-15 account for about two-thirds of the course credit.
XXIII.	**Related course offered by Instructor:**	The Instructor also teaches ***BENG/OMGT 5633: Linkages Among Technology, Economics and Societal Values*** which emphasizes a conceptual model called *LATESVOLOGY* (pronounced "lots-vol-ogy" which is an acronym of sorts: *LATESV (Linkages Among Technology, Economics, and Society Values; "OLOGY" - the study of)*. While ***BENG/OMGT 5633*** is not a prerequisite for ***BENG 5613***, portions of the *Latesvology* conceptual model may be used to provide the context for CDASM.
XXIV.	**Overview of Course Assignments:**	The course is "project-based and topic-driven" rather than "test-based and lecture-driven". A total of 2100 points may be earned from all assignments excluding any bonus points. ***NOTE:*** *Details about individual assignments are provided in separate documents/folders within Blackboard.* ***NOTE:*** *Partial credit may be given at the discretion of the Instructor for late submissions except where clearly stated otherwise.* Assignments are as follows:

	a. Assignment 1: Class Readings	***305 points*** - Class Readings (~61 articles at 5 points each with partial credit - typically half - given for late submissions) are defined in detail within Blackboard (Folder 2 for general information and Folder 3 for specific readings). Nearly all required readings in Folder 3 are linked to the MIT website (http://ocw.mit.edu/courses/sloan-school-of-management/15-988-system-dynamics-self-study-fall-1998-spring-1999/readings/). There are also some other readings that are suggested in Blackboard Folder 3 which offer bonus point opportunities for students. ***NOTE:*** *If the student reads all the class readings, he/she may claim 61 class readings even if the total number of required class readings is less than 61.*
	b. Assignment 2: Viewing Template Instructional Videos	***40 Points*** **-** Template instructional videos for using Excel and Vensim PLE to fulfil the Lottery and CDASM System Dynamics modeling assignments (4 videos at 10 points each). Folder 4 has the videos. Confirmation is to be submitted through Folder 7.
	c. Assignment 3: Viewing Lecture Videos	***150 points*** **-** 15 Lecture videos that are to be viewed (10 points each for viewing). These lectures are intended to broadly supplement the required reading material but are not intended to provide the same level of detail. Folder 5 contains the videos. Confirmation is to be submitted through Folder 8.
	d. Assignment 4: Blog entries	***100 points*** **-** 10 blogs with each focusing on a particular issue related to modeling (10 points for each blog). No credit for late submissions. Depending upon size and mix of term and semester class enrollment, interactions with other students may be required to receive full credit for a blog. See Folders 2 and 9 in Blackboard for the blog schedule and blog list, respectively, the latter being where entries and replies are submitted.
	e. Assignment 5a: Lottery Model	***400 points*** - 100 points for each of four versions of the "Lottery Model". This Model is to be programmed in both Excel and Vensim PLE. Detailed assignment instructions are provided within Blackboard in Folder 2, and Excel templates are available in Folder 1. Assignments are to be submitted in Folder 10. ***NOTE:*** *Reduced credit may be awarded at the discretion of the Instructor if submitted late. However, there is really no need to turn in work that is severely lacking in completion in that little partial credit will be given. This simply wastes the time of both the student and the instructor. Thus, it is far better for the student to turn in his/her best work late than to submit incomplete work on time.*
	f. Assignment 5b: Community Development and Sustainability Model	***1105 points*** - 100 points for each of 10 stages of development of the Community Development and Sustainability Model (CDASM) in both Excel and Vensim PLE (Sessions 5-14) to include a summary assignment in Session 15 (105 points). Assignments are to be submitted in Folder 10. ***NOTE:*** *Reduced credit may be awarded at the discretion of the Instructor if submitted late. However, there is really no need to turn in work that is*

		severely lacking in completion in that little partial credit will be given. This simply wastes the time of both the student and the instructor. Thus, it is far better for the student to turn in his/her best work late than to submit incomplete work on time.
XXV.	**Course grading:**	The course has 2100 possible points plus any bonus points that may be accrued. Grades will be given on the following basis: A=1900 points or higher; B=1700-1899 points; C=1500-1699 points; D=1200-1499 points; F=below 1200 points. Note the following concerning grading standards and bonus point possibilities:
	a.	For the formal written/oral report (Session 15), credit will be based on following the specific instructions but with attention given broadly to the following general areas: conclusions, calculations, data, data analysis, logic and assumptions, organization, grammar and overall appearance.
	b.	***NOTE:*** *For bonus points to be received, the student must also have received significant credit for at least nine of the 10 Stages of CDASM and the Final Report where "significant credit" is to be determined by the Instructor.*
	c.	Opportunities for bonus points are given in Folder 2 of Blackboard in a file that describes all the assignment requirements.
XXVI.	**Methods:**	The course is primarily project-based via the ongoing development of the "*lottery model*" and the "*Community Development and Sustainability Model*" (CDASM). However, there will be class discussion as directed by the respective blog questions which will draw upon some of the required reading and video lectures.
XXVII.	**Student-student and student-Instructor Interactions in class:**	Exchanges within the class are always to be respectful, professional and courteous but challenging in a manner so as to generate enlightened discussion that might even be a bit provocative at times. In fact, students should expect some "give and take" via the class blog assignments that are designed to enhance the learning environment and better equip the student for their roles as professionals, especially as related to the goal of sustainable prosperity and wellbeing. ***NOTE:*** *There is a special informal Blog set up in the Blackboard content so that students and the Instructor can post comments and questions for all to see during the term/semester.* ***NOTE:*** *Again, it is expected that the nature of this course will likely require some "one-on-one" contact with the Instructor by phone and/or email. So students should not hesitate in making such contacts as needed!*

XXVIII.	**Other goals:**	This is intended to be a "fun course" that can be life-changing in that it promotes visualizing, quantifying and analyzing macro-level systems in a different way, especially as related to sustainability. Be aware, however, that it may take several sessions before the System Dynamics philosophy and approach begins to be more fully understood.
XXIX.	**Other university guidelines, policies and regulations:**	The Instructor will make every effort to adhere to university guidelines, policies and regulations with regard to the course including the student code of conduct. This will include matters related to issues such as the cheating, plagiarism, ethical conduct, special accommodations, and inclement weather, the details of which are not given in this syllabus but rather through other official UA documents (some of which are prominently displayed within Blackboard). With regard to Disability Accommodation, the student should let the Instructor or the Center for Students with Disabilities (CSD) know if this is a situation that needs to be addressed.