FRAMEWORKS AND MODELS IN ENGINEERING SYSTEMS ENGINEERING SYSTEMS DESIGN (ESD.04 / 1.041)

SPRING 2007

PROFESSOR JOSEPH M. SUSSMAN **3-0-9, U (SPRING)**

PROJECT ASSIGNMENT #3 (P3)

DISTRIBUTED APRIL 10, 2007
FINAL REPORT DUE MAY 17, 2007 WITH SEVERAL INTERIM MILESTONES AND DELIVERABLES

Designing the Final Robust Bundle for SNF/GCC System

Summary of important dates:

Tuesday, April 10	**P2 due, P3 distributed and discussed**
Wednesday, April 18	**Email submission of draft strategic alternatives to your mentor**
Thursday, April 19	**Individual team meetings during class with mentor to select strategic alternatives**
Tuesday, April 24	**Individual (sequential) team meetings with DoE secretary to choose strategic alternatives for evaluation**
	Qualifying problem due
Tuesday, May 1	**Final report outline due for discussion next class with DoE secreatary**
Thursday, May 3	**Individual (sequential) team meetings with DoE secretary to review progress and for approval of final report outline**

Thursday, May 10 **"No fault" oral presentation rehearsal (back up date, Sunday, May 13)**

Tuesday, May 15 **Oral presentation**

Thursday, May 17 **Written full P3 report due**

Introduction

The Department of Energy (DoE) has received your "P2" report. It likes the imagination you displayed in your initial strategic alternatives. Now, DoE wants you to choose among them (perhaps including them all and perhaps even adding some others you didn't think of in P2) to form a *robust bundle* of strategic alternatives. In addition, there are several strategic alternatives that the DoE secretary insists that you consider whether or not you had them in your P2, about which more detail is provided below

So, now we enter Step 9, **Evaluate Strategic Alternatives and Select Robust Bundles,** which involves a more detailed evaluation and selection of the strategic alternatives. This will allow the DoE to make a final decision on how to proceed with the question of the management of spent nuclear fuel and related global climate change (GCC) issues. What DoE will ultimately want to do is choose the stronger of the two bundles proposed by you and your competitor, considering how good your strategic alternatives are and how they fit together to form a robust bundle.

We want to stress that for the entirety of this assignment, we ask you to work in groups. The CLIOS Process, as well as consulting work in general, produces much better results when the team works as a team, rather than seven individuals. There is a lot of work to do on P3, but you have seven people to do it. A key learning from this exercise will be getting yourselves organized to do the work. As with CLIOS Systems, there is "no right answer" to how you organize yourself; many schemes would work. But you do need to "design" the way your team will work together to complete this lengthy assignment.

DoE Sign-off on Bundle

On **April 18**, you should submit your bundle of draft strategic alternatives to your mentor by email. Then in class on Thursday, April 19, you will meet with your mentor to refine this bundle.

Then, the following week, on **April 24**, you and your mentor will meet with the DoE secretary (as simulated by Professor Sussman) to propose your bundle. You of course, for business reasons, want DoE to ultimately select your bundle, because there is likely to be more consulting work for the firm whose bundle is selected in the implementation stage of the CLIOS Process. So it is in your interest to craft a bundle that has a better probability of being selected by DoE for final implementation. The DoE secretary may have some suggestions at this time, but at the conclusion of this meeting, you will have agreed with the DoE secretary on the bundle you will consider in Step 9.

You will then get to work on the detailed evaluation and selection questions associated with creating flexible alternatives that make up your bundle and demonstrating your bundle is robust.

Qualifying Problem--Risk Assessment and Benefit-Cost Analysis

But first there is another hurdle! DoE is convinced that risk assessment and benefit-cost analysis will be fundamental to evaluating the SNF/GCC strategic alternatives. So to be sure your team can deal with these methods the secretary has decided to give each firm a qualifying problem using these methods to see if your team is up to the task. This qualifying problem is attached in Appendix I and is **due on April 24**.

After the qualifying problem is complete, the DoE secretary (and his trusted staff) will look over the results of each team's analysis. If he deems your firm fit to continue (and remember, there is a big contract at stake, so you need to do your very best work), he will then expect a full written and oral report detailing the results of your robust bundle evaluation and selection, as explained below.

Step 9 – Evaluate Strategic Alternatives and Select Robust Bundles

On **April 24**, you meet with the DoE to present your preliminary bundles and to agree with him on the bundle you will study in Step 9. Now he wants you to perform the full evaluation and selection so that when he meets with key senators and power and transportation industry executives in a few weeks, he has something concrete to discuss. (He has been told that the President of the United States and Secretary-General of the UN have expressed interest in this study, given the energy, environmental and geopolitical issues at stake, so he is under substantial pressure to deliver)

Some of this pressure comes from his colleague on the President's cabinet, the Secretary of the Department of Transportation. She has been strongly urging the DoE to perform a full risk analysis of the transportation option of SNF to Yucca Mountain, so that they can begin their preparations as needed. They also want a backup option to be able to ship SNF to (presumably smaller) temporary sites, in case the Yucca Mountain project falls through. Eerily, this parallels the qualifying problem you did above with artificial data.

So in addition to the strategic alternatives you agreed to consider in your meeting of April 24 with the DoE secretary, he asks that you perform a risk assessment and evaluation exercise, this time using real world data and solid reasoning and assumptions (be sure to ask your mentor if you need help finding this data).

More specifically, the secretary insists that the following four strategic alternatives be included in your final report:

1. Risk assessment/Benefit-Cost analysis for both rail and truck transportation of SNF to Yucca Mountain

2. Risk assessment/Benefit-Cost analysis for both rail and truck transportation of SNF to temporary sites, which will be located and sized by your firm

We have provided a guide to help you with this section, which is attached in Appendix II.

Of course, the DoE is also very interested in your own other strategic alternatives for **both SNF and GCC**, and certainly wants analyses of those included in your final report as well. It is certainly possible that evaluating those strategic alternatives will also require some kind of benefit-cost analysis and/or risk-assessment as well, but perhaps some other methods might be more useful.

DoE will be interested in how your bundle performs across the various scenarios outlined in P2. *Specifically, DoE will be interested in how your bundle can scale up or scale down smoothly, as the actual energy picture and use of nuclear power plays out over the next 25 years.* You may want to include some other scenarios as well, that DoE did not specify.

Overall, the DoE expects your work to show some consistency betwen the understanding of the CLIOS System you gained from completing P2 to the final recommendations you make.

Strategic Perspectives

In addition to the detailed design, you are well aware that the DoE secretary (Prof. Sussman) likes strategic perspectives in the reports he receives and fancies himself a broad thinker in the domain of complex socio-technical systems extending to the international theater. So your report should include some of these strategic perspectives.

For example, you probably want to have some discussion of the overall energy picture the United States faces and will face in the future, and you will also probably want to show that you understand the geopolitical situation that relates to energy sources of various sorts. You will want to show that you understand 1) who are the various stakeholders concerned with the management of SNF and with GCC and 2) how they might react to your bundle of strategic alternatives; perhaps a preliminary idea or two as to how your bundle could be "marketed" given the "evaluative complexity" that permeates this problem would be helpful. Some sense that you understand the various attitudes toward nuclear technology and GCC and other environmental issues in the United States would also be helpful.

Report Structure

As you proceed with your efforts, you should work closely with your mentor at creating a good structure for your final report, capturing the ideas the DoE secretary has expounded upon above. In addition to the April 24 meeting with the DoE secretary to make a selection of strategic alternatives, he has agreed to meet with your consulting team (and of course the other one separately) and your mentor, for an interim progress report on May 3 where you will present your report outline and, in general, give the secretary some comfort that you are on the glide path to something that he can use in his final decision making process and in his meetings with the various heavy hitters noted above.

Deliverables

The **final deliverables** on this P3 project are as follows:

Written report Final report is due on Thursday, May 17, the last day of classes. The report should be up to 30 pages (minimum 20) plus any appendices you may include. The report should provide detailed explanations and analysis of individual design components and include the anticipated impacts of the bundle on different areas of the SNF/GCC management system.

Oral Presentation Final presentations will take place on May 15. The presentations will be 30 minutes with a 10-15 minute Q/A session. The presentation need not involve all group members, but more than one member should present. We have built a rehearsal day into the class schedule on Thursday, May 10. Just for your information, last year both teams preferred to rehearse on Sunday evening, May 13 with their mentors and Prof Sussman. We can leave this flexible for now. In either case, the rehearsal is "no fault". Your project grade will NOT be affected by the quality of your rehearsed presentation. We recall that both teams last year showed a remarkable positive delta between the rehearsed and actual presentations!

You are free to use any presentation techniques, tools, and/or devices in order to for you to convince the DoE secretary (and his advisors) of the effectiveness of your proposed final bundle.

Some Guidance

Now, shifting back into my guise as Professor Sussman, here are a few additional comments.

Is this assignment amorphous? Absolutely. That's the idea. That is almost always the case with the design of CLIOS Systems. We have reduced the uncertainties in the assignment with several interim interactions with the DoE secretary and of course, ongoing interactions with your mentor that will help keep you on track. But if ever there was a case where there is "no right answer" to an assignment, this is such a case. And that's fine!

There is a huge amount of publicly available information on this domain. The issue won't be finding information; it will be deciding what is relevant and using that effectively. Your mentor can be helpful, but perhaps you want someone on your team to take the lead on developing information sources and screening for useful ones.

Your firms need names. Please choose something you like. It's easy and it can even be fun. Just remember you will have to be able to say it with a straight face during the expected professional quality oral presentation.

There is a significant amount of work to do to produce a credible report and presentation. However, this is all you have to do in this class until the end of the term and you have a lot of talent (seven MIT undergrads) to get it done with. This is, in part, an exercise in getting organized, which involves figuring out what work you have to do collectively as a team, as opposed to what work can be done by individuals that can then fold back into an overall report. We do expect an integrated report, and as I have told classes in the past—who haven't always listened--- a staple gun is not a useful integrating device for a consulting report if it is to be intellectually consistent and coherent from a style perspective.

Finally, you can assume the instructing staff is more-or-less rational. We are fully cognizant that the 'world" hasn't been able to "solve" the SNF problem despite huge efforts. So we really don't expect you to "solve" it in part of one semester! What we do expect you to do is demonstrate your understanding of CLIOS Systems and the challenges inherent in designing them (that is, in developing viable strategic alternatives and forming them into robust bundles) and to show the imaginative and sound thinking we expect from MIT undergraduates.

APPENDIX I: QUALIFYING PROBLEM

DISTRIBUTED APRIL 10, 2007 **DUE APRIL 24, 2007**

In Parts 1 and 2 you are expected to base your answers only on the given data. Note that these are stylized for simplicity. This is for practice; you will have the opportunity to do this problem using more realistic data. The intent is to give you some practice on a simple case before you launch into a full-scale study.

System Description

We will consider a simplified situation of the SNF transportation and storage CLIOS System as shown in Figure 1. There are 6 sites where SNF is currently stored numbered from 1 to 6 and marked as grey triangles on the map. There are two proposals for storing the fuel: (i) using a single centralized long-term facility (Marked X), or (ii) using two shorter-term smaller centralized facilities marked A and B. Finding acceptable sites for this use was hard and their position currently satisfies both political and scientific constraints for the anticipated length of storage. As a result identifying other potential areas or routes is not an alternative at this point. The transportation of SNF is expected to be completed within 10 years. SNF can be transported either by rail OR by truck – i.e. no hybrid transportation solutions can be implemented.

Table 1 displays information about the network routes that have already been found to provide the minimum exposure of general population while SNF is en route.

Table 1: Network distances and Population Centers

OD pair	Highway Distance (in miles)	Number of Cities	Population	Rail adjustment
1A	300	1	300.000	x1.1
2A	150	3	100.000 each	x1.2
3A	350	1	50.000	x0.9
4B	150	3	75.000 each	x1
5B	200	1	50.000	x1.3
6B	300	1	1.000.000	x0.8
BA	1000	4	100.000 each	x1.1
AX	1500	5	50.000 each	x1.1

Note that for rail access multiply the distances by the given factor.

Assume that all urban areas have a radius of 5 miles.

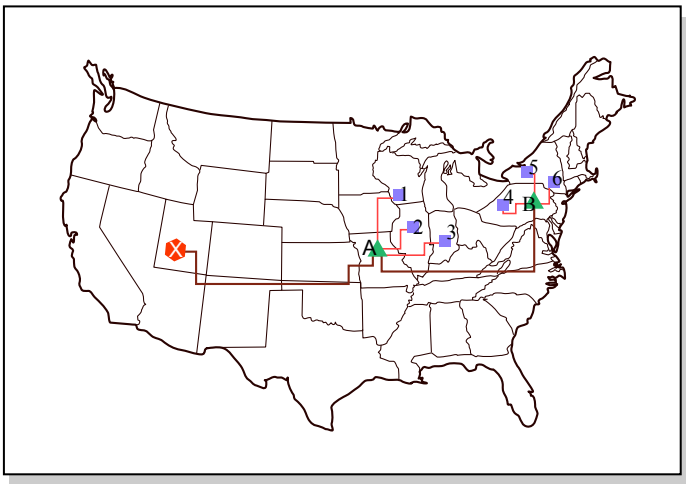

Figure by MIT OpenCourseWare.

Figure 1: SNF System Network (not in scale – for illustration purposes only)

The amount of SNF in each site has been calculated in container loads for your convenience (you have good staff!) as shown in Table 2.

Table 2 SNF Quantities in Container loads

1	2	3	4	5	6
2600	3000	4600	1000	4000	5000

Trucks carry 1 container load per trip while trains carry 20 container loads per trip.

The cost of transporting **one** container by truck is $5/mile while the same figure for train is $1.5/mile. (SNF transport is expensive!)

From historical observations, the accident probabilities for the two modes have been established. For intercity travel the accident probability for truck is $P_{truck\_accident} = 10^{-6}$ per truck-mile while the corresponding probability for trains is $P_{train\_accident} = 10^{-7}$ per train-mile. For urban travel this probability is doubled, because of traffic volumes, higher number of railroad crossings etc.

If an accident happens, then the probability of a significant leakage of radioactive material has been calculated based on drop and puncture test performance to be on average $P_{release} = 10^{-4}$ for **each** container carried. Container leakage in a given incident is independent of whether other containers have leaked or not. We assume that the consequences (health effects and restoration work) are the same if one or more containers leak in the same accident.

All containers carrying SNF will be equipped with tracking equipment that notifies the emergency response teams if it senses an accident. The probability that the GPS is affected by the accident and does not signal is $P_{GPS\_failure} = 10^{-2}$. If the system does not fail then the emergency response teams can arrive at the accident site early enough to prevent severe contamination with a probability of $P_{mild\_ER} = 0.7$. If they arrive late, $P_{mild\_ER} = 0.2$.

The costs for decontamination and toll on economic and population health have been estimated on an approximate basis and shown on Table 3.

Table 3 Event Costs

Event	Costs
Urban Mild	$100M*(S/100.000)2
Urban Severe	$1B*(S/100.000)3
Rural Mild	$10M
Rural Severe	$100M

where S is the urban area population size.

Part 1: Risk Assessment for the Transportation of SNF

You are asked to do a risk assessment for the transportation of the SNF which requires you to calculate certain risks for both the truck and rail transport options.

The following suggestions/questions will guide you in this effort.

1 Identify the solution space (bundles of strategic alternatives) implied by the problem formulation.

2 For the bundles of strategic alternatives you identified, calculate (or identify from the problem description) the following data for operation of the project for 1 year:

- a. Expected value of number of accidents for rural and urban settings.
- b. Probability of leak if an accident happens
- c. Probability of GPS failure if an accident happens

3 Now you are ready to provide an event tree for each bundle to aid your calculations of end probabilities.

4 Using the event trees, calculate the end probabilities for having zero incidents, mild incidents, or severe incidents. What are the expected values of their costs, given an accident occurs?

5 Which combination of storage site and transportation mode would you recommend?

6 A research fund has been designated to improve reliability of the SNF transport. One of the alternatives you face is making the GPS unit more reliable; in this case this means to reduce the probability of failure in case of accident from 1% to 0.1%. Assuming that the purchase price of the GPS unit remains the same, how much money would you be willing to invest in this research?

The use of a spreadsheet like Excel is highly recommended. You could also use decision analysis software e.g. the evaluation version of TreeAge or the Palisade PrecisionTree to draft the event trees but this is not necessary for completing the assignment but you may find it of value to look into this software if you are interested in professional decision-support tools.

Part 2: Project Benefit Cost Analysis (BCA)

Based on the expected values (costs) of accidents in the above scenarios and transportation costs, you are asked to conduct a BCA using solely net present value (NPV) comparisons to evaluate total project costs. Assume that all costs accrue on the beginning of the year. Perform the evaluation for two discount rates of 5% and 15% respond to the questions below. Assume no inflation.

Table 4 Costs

Cost Type	Cost	Projected Life (in years)	Maintenance Costs	Restoration Costs
Long-term Central Facility Construction	$1B	>1000	$1M per year for the first 100 years	$0. At the end of the facility life, the SNF would be rendered harmless
Short-term Facility Construction (both facilities)	$200M	50	$4M per year for the life of the project.	At the end of the 50 year period there is a 50% probability that the stored SNF will actually be used by newly developed technologies which would bring a benefit of +$200M. Otherwise a permanent facility should be constructed at a cost of ($1B).*

* ignore all related transport costs for this case – teleportation would be feasible by then anyway ☺

The rail solution will require a $150M investment for the long-term central facility construction and $50M for the temporary facilities.
a) What is the NPV of the bundles of strategic alternatives you identified in Part 1?

b) What is the strategic alternative with the lowest NPV?

c) If, for political reasons, the decision-makers decided to go with the permanent storage is it cost effective to build the rail spur to access the site?

d) In the calculations above, we did not take into account any variation in the risk associated with the different storage alternatives. Which storage alternative is riskier in your opinion? What difference in the annual expected cost from extra risks would make the other storage alternative more preferable than one you indicated in (b)? What is your preferred strategic alternative? Why?

APPENDIX II: TRANSPORTATION ANALYSIS GUIDE

The qualifying analysis assignment you submitted on April 24 was intended to give you some practice with the concepts and mechanics of risk assessment and benefit-cost analysis. While it was loosely oriented around SNF transport and storage, the locations, numbers, and costs were entirely fictitious. This assignment had a correct answer and therefore allowed DoE to evaluate whether you understood the process. Now you need to perform this study "for real".

We will guide you in the process of actually going through most of the important steps that you would have to do if you were actually doing this analysis for a client and facing the uncertainties of the 'real' world. In the CLIOS Process nomenclature, this analysis is part of Step 9. That is, you will be evaluating and comparing strategic alternatives across different scenarios.

You are required to evaluate four strategic alternatives bundles:

1 Risk assessment/Benefit-Cost analysis for both rail and truck transportation of SNF to Yucca Mountain

2 Risk assessment/Benefit-Cost analysis for both rail and truck transportation of SNF to temporary sites, which will be located and sized by your firm

In order to help you with structuring your work, we provide you with the following suggestions for structuring this work. But note these are suggestions and not commands!

(The parentheses after most items provide some suggested actions but they are neither required nor exhaustive.)

1. Define your strategic alternatives.
    a. Locate the US nuclear power plants and estimate the SNF quantity they have stored and are going to generate in the future

based on ONE scenario described in P2 for the future. (back of the envelope calculation based on MW capacity but you have to find the formula for that).

   b. Define the number and locations of the facilities in the strategic alternatives using some logical criteria (isolation, proximity to existing facilities, minimizing total exposure, somehow reduced NIMBY problems, etc.)
   c. Decide the max capacity of SNF for each facility by choosing which power plant will store their SNF there. What is the construction cost for each facility? (Publicly available reports and similar literature may provide ballpark figures).

2. Quantify the costs and risks of transportation.
   a. Quantify the probability of accidents for trucks and trains (use the BTS website for data)
   b. Estimate the costs of transportation per container mile (use commercial websites, BTS, or any other source you believe is relevant. Don't forget the hazardous nature of the cargo).
   c. Estimate the probability of release if an accident occurs (use the NSF report on container reliability).
   d. Calculate the distances of travel and find the major metropolitan areas for truck and rail (straight line approximations or even broader assumptions are acceptable, but if you want more detail, Google maps can provide exact mileage estimates for trucks and the freight railroad sites could provide maps of the existing rail network).
   e. Quantify the costs of a hazmat accident (anyway you think appropriate – compare to known catastrophes from New Orleans post-Katrina to chlorine container fires, estimate affected populations, insurance quotes, etc).
3. IF you believe that your strategic alternatives exhibit other risks, costs or benefits, then you should structure those in a similar fashion. (Some areas to consider: terrorism vulnerability, flexibility: e.g. the value of SNF as fuel for reprocessing and benefits from postponing a final solution, construction of dedicated transportation infrastructure).
4. You are now ready to construct event trees with the probabilities of accidents and their costs. Doing a benefit-cost comparison, you can evaluate each alternative based on capital costs, transportation costs, and risk-related costs.

5. Decide which alternative you would recommend and explain how you think it would behave under the other future scenarios described in P2. (further calculations not required but welcomed).

Of course we understand that you have neither the resources nor the time to make a complete assessment of the issues at hand. What you can do though, is demonstrate the quality of your thinking and the meticulousness of your research. You can reveal these qualities to us if you try to adhere to the following guidelines:

1. Document your thought process and actions.
2. Reference your sources and provide copies, if applicable, in appendices.
3. When you make assumptions, and you will have to make many, support them with logical arguments.