# Launching System Dynamics

James H Hines
LeapTec and M.I.T.
144 Edgewood Blvd.
Providence, RI 02905
USA
Tel: 401-467-9292
Fax: 401-941-0412
E-mail: JamesHines@Bix.Com

Dewey W Johnson
Eastman Chemical Company
P.O. Box 511
Kingsport, TN 37662-5054
USA
Tel: 615-229-5679
Fax: 615-229-6099

**Abstract**

It is increasingly common for companies to undertake a system dynamics study with the aid of outside consultants. However, it is still *uncommon* for even large companies to successfully bring system dynamics into the organization as an internal competency. This paper reports on the efforts at Eastman Chemical Company to create an internal capacity in system dynamics. At this point, Eastman has successfully launched system dynamics as an organizational approach to decision making, and the effort continues to develop rapidly. Eastman managers must yet address issues of sustainability, however the process that resulted in a successful organizational start is of interest in itself and may help other companies seeking competency in system dynamics. This paper describes the launch of system dynamics at Eastman.

# Launching System Dynamics

## I. Prerequisites

Our efforts have benefited from a few conditions that came for "free" at Eastman and a few that we have explicitly engineered (or will engineer in the future).

**Fertile ground.** Although we hope that the lessons described here will be helpful to any company, we do not want to hide the rather unique strengths of Eastman. For example, Eastman is largely populated by people with technical backgrounds, usually in engineering. There has long been some question in the field about what *kind* of people find system dynamics most congenial. However, there can be little doubt that people who are used to using models in ways similar to ours have an easier time understanding the system dynamics technology.

Another advantageous characteristic of Eastman is that its core business involves liquids that flow and accumulate. Everyday experience at Eastman corresponds to the rate and level structure of our dynamic models, and to the fluid metaphor that underlies our stock and flow diagrams. The success of system dynamics at companies managing similar processes (e.g. Shell and Exxon) might support the notion that companies involved in managing stocks and flows have a leg up on companies that do not.

Finally, and most importantly, total quality management has taken deep root at Eastman, which won the 1993 Baldrige Award. As a consequence, Eastman's orientation is toward continuous improvement of business processes. The managers at Eastman have no trouble viewing management as a process that can be specified, even diagrammed, as opposed to, say, a talent. They are not looking for the fast-break play that will transform the organization in one blinding moment. Rather, managers are quite comfortable with the idea that managerial processes, like any business process, can be gradually and continually improved..

**Modeling for insight.** We have focused on a particular use of modeling. We have tried to help managers gain insight and control, rather than to make point predictions. For example, in one case we helped provide a framework for increased alignment between two groups who need to work well together on the large (100+ million dollar) construction projects that mark Eastman's incremental growth. In another case we helped a division discover a responsible negotiating objectives during the recent spin-off of Eastman from Kodak. In another application we worked with a group of managers wondering how to respond to an anticipated fall-off in demand for their division's services as a result of the current slump in the chemical industry. In each case the system dynamics process led to clarification of options and more clear-sighted decision making. For example, in the last case the managers decided that they need to have the courage to do nothing: Demand for their particular product would turn around before the end of the slump.

An emphasis on insight corresponds to the interests of the managers who support the wider use of system dynamics. However, the transformative power of system dynamics comes from its insight generating capacity, and consequently we think we are leading with the very heart and soul of the discipline. There are also strategic, pedagogic and economic reasons for our focus. Predictive models tend to be large, have an appetite for data, and tend to provide most of the payoff at the end. This is precisely the opposite of what is required for an initial foray into the field. We need models that people in the organization can participate in building, we need to keep costs down, and we need to get benefit fast and continually. It may very well be that these needs are not unique to the launch-phase of system dynamics.

**Lengthy preparation and fast first crop.** At Eastman the interested managers spent about a year in discussions about systems thinking before embarking on the first crop of system dynamics projects. During this period, a group of six managers met monthly to discuss broad issues in systèms thinking. The discussions began around Peter Senge's *The Fifth Discipline*. The issues considered were how the ideas presented in the book related to the reality of Eastman. It was some months before the managers even realized there was a field called system dynamics that provided the rigorous foundation for some of the most interesting ideas. In retrospect, this year-long preparation was extremely important. By the time a real system dynamics project was undertaken, the big ideas -- feedback, structure vs. behavior, and leverage -- were firmly established in the minds of the group. Of the four members of the first project team, three had spent many hours considering the purpose and outcomes appropriate to a system dynamics process.

If Eastman had represented fertile ground to begin with, the discussions around the Senge's book, supplemented later with Systems Thinker, provided the preparation of the soil -- clearing and plowing the field. The preparation phase meant that the advocates of the approach had a deep appreciation for it, knew what realistic objectives were, and could communicate the purpose of the effort to other managers.

## II. The Unfolding Process

**Process overview.** We began by following the traditional sequence: reference mode --> hypothesis --> model --> analysis (Randers 1980, ch 6; Richardson and Pugh 1981, pp. 15-17). And we find that in circumstances where the stock and flow structure is unclear (e.g. competitive dynamics), that procedure is highly reliable. However, in situations where there is a prominent stock and flow structure (e.g. project dynamics), the traditional method tends to move toward more abstract ideas. In these cases it now appears that it is more effective to simply jump in with a stock and flow portrayal of the system. This second approach is probably as wide spread in practice as the "traditional", but it is not highlighted in the literature (but, see Anderson and Richardson).

Eastman has used an "extensive" process (Richmond 1991). Others,, have met with recent success from an intensive process -- a single intense meeting that might last one or two days Richardson and Andersen 1994 and Andersen and Richardson 1994). Although we will likely experiment with an intensive process at some point in the future, to date the projects at Eastman are typically spread over several weeks or months.

Generally, a project team meets for one day each week for the duration of the project. This is a heavy load for executives who are busy with other tasks, but an important problem will draw that kind of participation: We have gotten regular participation from people up to assistant-division head level, and intermittent participation from division heads. (A division at Eastman might include from 600 to several thousand people).

The conceptualization phase of the project, in which a causal diagram or stock-and-flow diagram is completed, sometimes has an "intensive" feel to it. For example in one project we completed reference modes and a causal diagram in a single day, and had time to do some policy analysis. However, we play things a bit loose and let people know that if we don't finish the diagram during the first meeting; we're still going to be O.K.

There are several reasons we use an extensive process: First, we have generally operated with a single facilitator/modeler (in contrast to Richardson and Anderson), although this will change as the internal consultancy becomes more expert. Hence, there is no one to sit off-line and create attractive, simple diagrams or models. Further, our efforts often result in a medium sized model (200-400 active equations) or in rather complex stock-and-flow or causal-loop diagrams. Since our efforts might include twelve day-long meetings, spreading these over a period of months rather than having a two-week off-site makes sense. Finally, a period of reflection between meetings has seemed valuable to us. We have used this time to consider where we want to go with the effort, to restructure a group, or simply to get a bit more work done on a model prior to the next meeting.

**Project prep.** The project preparation consists of the education, advocacy, and raw footwork required to get a group of people committed to doing a project and ready to dig in. We provide a few words on selecting projects in our observations section below. Education, though, is important to the early success of a project. System dynamics is not like other approaches to dealing with an issue. We are looking for insight, an item not found on the agenda of typical business meetings. Further, we use feedback concepts, system dynamics diagramming conventions, and stocks and flows, none of which may be familiar to the managers that we'd most like to involve.

We kicked each of the first two projects off with a two hour meeting on system dynamics, most of which was devoted to an introduction to the field. The introduction received generally favorable responses from the participants. Nonetheless, we have since concluded that this two-hour introduction is not necessary. Instead, we now distribute two pamphlets to participants prior to the first meeting. The first is a system dynamics comic book (Godfrey and Evans 1992) and the second is a very simple introduction to system dynamics (Kauffman 1980). Our feeling is that the BP comic book alone may be sufficient.

We are evolving in the direction of pushing more and more of the learning into the actual accomplishment of work. This seems more efficient and provides the right motivation for Eastman's practical, practicing managers.

**Reference modes and diagramming.** The first meeting has usually been devoted to drawing reference modes and developing causal loop diagramming. We don't have enough experience with the flow situations to give a typical sequence for jumping into the stock and flow diagramming. However, the sequence for a causal loop kind of problem is pretty clear to us now:

1. *Story time.* The first thing is for the manager who owns the problem to explain what has brought us all together. His tale typically takes the form of a chronologically organized story about what has given rise to the issue as well as a description of the issue. This serves to bring everyone up to date and allays fears that we (i.e. the system dynamics team) don't know what the situation is. In fact, the explanation does indeed ground us in the problem The story can take from five minutes to half an hour.

2. *Picture time.* The next task is to convert the story into pictures -- hand-drawn reference modes. The purpose here is to move firmly into a dynamic frame of mind, identify key variables, and to make sure everyone is thinking about the same issue in similar ways. In short, the purpose is to "crisp up" the problem.

   Often the story itself will suggest a number of key variables to hand-plot. In this case, the facilitator can suggest a couple of candidates, so that the participants can understand what this step involves. In the first few projects we drew reference modes for each variable suggested by a team member. We finally realized that this can be extremely time consuming and that not all the reference modes generated are truly central -- that is, not all the plots were subsequently used for reference. Now, we list variables first, and then choose which ones are central enough to draw.

Most of our issues are not retrospective and consequently the interesting part of the plot is the part that moves on from now into the future. We encourage people to draw multiple possible futures, explaining the differences between each one. For example, a plot for demand in a situation where a new competitor is coming into the market might involve two futures -- one where Eastman demand goes down and stays down and another where Eastman's demand goes down and recovers. The second future corresponds to one in which where the competitor "stubs his toe" due to start-up inefficiencies.

The team often feels it has accomplished something by being able to draw their problem. Sometimes insights emerge simply in the process of drawing plots. Always the team is more aligned at the end of the several hours devoted to reference modes.

3. *Theory time.* The system dynamics process turns managers into scientists. The critical point in science is theory building, and the system dynamics process helps by defining what kind of theory to create and providing conventions for representing the theory diagramatically. We are looking for theories of how the system itself (which may include only the organization or may extend to customers and suppliers) can generate the reference modes. These theories are expressible as causal loop diagrams. The output from this stage is a large diagram of interlinked loops that typically represents six to ten separable explanations of the reference modes.

In our experience the movement from reference mode to dynamic theory is not easy for the managers. This may be due to the limited exposure of the managers to the basic structures that can cause fundamental behavior patterns (exponential growth (and collapse), s-shaped growth, adjustment, and overshoot). In any event the development of causal loops has required the very active support of an experienced system dynamicist.

The time required to get a satisfactory set of loops has varied from several hours to a couple of days (naturally the loops continue to evolve during the life of the project). The effort is quite worthwhile. The diagram -- which we clean up and store on a CAD system -- guides the computer modeling effort and it also provides a map for discussions of the team. In subsequent meetings we have a large diagram on the conference table. When people make points they point here and there on the diagram. Communication is at once clearer and faster. Diagrams can take on a life of their own. For example, we produced a causal loop diagram of a conflict between two groups. The system dynamics team actually thought the effort was not successful. Much to our surprise we learned that the diagram was copied and passed from hand to hand in the divisions concerned.

4. *Payoff time.* At the end of the first day, even if we are sure we'll spend another day on diagramming, we always make time for policy analysis. The participants have worked hard, and they deserve a payoff. Our policy analysis usually takes the form of focusing on a single undesirable loop (positive loops work well here). We think up ways to break *each* link in the loop. For example in a positive loop where work to do leads to overtime, which leads to fatigue-induced errors and hence more work to do, the link between fatigue and errors might be

broken by changing the tasks being worked on after a certain number of hours at work. We generate several flip chart pages of policy possibilities. The participants see how it is done, and could continue in our absence. In fact, we suggest that they do, although we think they don't. Clearly for a project where there are no subsequent phases, this policy analysis step should be extended, with or without the internal and external consultants.

At the end of this phase, participants should feel that they have already gotten significant benefit. Indeed, our objective is that this and each meeting subsequent produces results -- insights or decisions. Generally speaking we have not found it hard to deliver on this objective. We definitely discourage the notion that we need to wait until a model is "complete" before drawing conclusions or taking action. The reality, of course, is that all conclusions, insights, and decisions in business are tentative, they hold until they don't. The system dynamics process is no different.

**Core model and incremental addition.** We develop computer models incrementally by successively adding the hypotheses (see immediately above). We treat each incremental completion as a new model and, ideally, analyze it and use it for gaining insight. Typically, we might analyze a new model version in one meeting and then in the same meeting design the next incremental add-on, which will provide the model for the following meeting. In this way, the model is almost always "complete", well understood, and yielding insights and policy ideas

Not all managers have the patience or the interest for actual equation writing. Consequently, in our most recent projects we have done the equation work in a subcommittee of the group. The subcommittee might include only two or three people, where the entire group might include eight.

**Ending the project: Handing off to the owners.** Not very much needs to be said here. At some point the involvement of the external and internal consultants comes to end. The issue needs to be turned back over to the managers who have the problem. This has never been a problem at Eastman. We try not to take offense, but the management teams seem very willing to kick us out and take over the process.

## III. Observations

**Finding good problems: The importance of important issues.** People new to system dynamics understandably look for test problems that won't cause significant career or organizational damage if they go awry. This often translates into a search for unimportant problems. Unfortunately the chances of failure are much greater for an unimportant project than for an important one. The system dynamics process demands the time and effort of relatively senior (and always busy) managers. It is simply not likely they will commit their own time or their subordinate's time to unimportant issues.

On the other hand, the issue, though important, should not be too pressing: The system dynamics process takes time measured in months, at least if a computer model is desired. A good issue is often one that :

- is chronic (won't go away)
- affects performance
- has a time frame of six to nine months
- has an identifiable sponsor who has control of funding, human resources, and the ability to implement modeling insights

At Eastman our early focus has been on line management needs, focusing on areas affecting money flow (e.g. - demand, pricing strategy, competitor response, technology engines for growth). We have avoided the support organizations' needs (e.g. effectiveness of teams, training effectiveness, etc.).until a later phase This reflects our orientation toward high-visibility projects that obviously affect the business for clients who have authority to implement results.

**Advocacy and a budget.** Clearly problem selection is important, and clearly it requires an insider. At Eastman, there has been a strong advocate (one of the authors) who has knowledge of what the hot issues are and which issues are too hot. In addition the advocate's standing and connections within the organization are such that he can influence senior managers to try a system dynamics process. Finally, the advocate has a budget out of which he has funded the initial projects in a number of areas other than his own. It appears that managers are more willing to spend their own time on, and assign subordinates to, a promising new approach than they are to spend cash.

**Outside expertise, and an internal group.** The "seed" funding has gone to internal labor, which is necessary to gain an internal competency and for external expertise which is necessary to quickly move up the learning curve and to gain quick and meaningful successes. The use of an outside consultant (one of the authors) has, form the start, been geared toward avoiding the sort of shifting-the-burden process that can lead to long-term dependency. Several concrete steps have been taken to avoid this dependency.

First, we have kept a careful eye on what might be called the "backroom ratio", the ratio of the consultant's time spent with the client to his time spent working alone (i.e. in the "backroom"). The ratio needs to be high enough for the client to get the exposure necessary for learning. We began with a backroom ratio of about 50%, meaning that half the external consultants time was spent away from the client. Today, the ratio is 100% -- all of the consultant's time for Eastman is spent with Eastman people. Another important measure is the "boosted-client ratio", the ratio between the time the consultant spends working with (i.e. boosting) the client and the time the client spends working without outside aid. At first, the ratio was about 95%, reflecting the fact the consultant was engaged in all activities except converting causal loop diagrams to CAD. Today, the ratio is about 10% -- Eastman is largely independent of the consultant.

Second, Eastman has established a network of contacts with some of the most experienced people and organizations in the field. These connections help both Eastman and LeapTec keep it straight that they are independent organizations. The "main" outside consultant has been helpful in "mapping the field" for Eastman and in providing introductions to other academics or consultants.

Finally, Eastman has taken what we believe will prove to be the most important step to establishing an internal system dynamics competency: Eastman recently established an internal system dynamics group, known as the "system dynamics focus group". An internal group is important for a number of reasons:

- When gaining competence in a new discipline, people need to talk about problems they are having, need sanity checks (i.e. "This looks good to me. *Is* it good, or am I nuts?"), need support to take the sting out of the inevitable stumbles, and finally they need a group which will be interested in what they are doing. Consequently it is important that system dynamics people be brought together, rather than dispersed through the organization.

- A central internal resource makes it easier for other areas in the company to try the new approach. The internal group costs less than outside consultants, is more knowledgeable about the business, and can be "felt out" about feasibility at lower personal investment. Further, areas in the company can efficiently use an internal group for implementation and additional experimentation. (Three of the completed models have designated stewards for maintenance and continued experimentation of the models).
- The existence of the group makes it more likely that a number of people will get the sustained and varied exposure to system dynamics that is necessary to really becoming experts.
- The group is already a repository of case histories and success stories. Members of the group can tell potential clients about how the approach has been applied elsewhere in the company. The group also can draw on previous Eastman models for structures and insights to apply in new situations.

**The project group.** We always work with a management team that owns an issue. The reasons do not need great elaboration: 70% of the value of a model is probably in building it; working directly with the team lets them get most of that benefit. Our groups include the decision makers.

Most of our groups have been about six to eight people including the two authors. We tried once with a group of sixteen, which seemed too large, although we were also tackling a divisive issue for which a small group might have been particularly important. It might be best to think in terms of "effective" group size; that is, the number of people who are active in the discussion at any one time. Four people (including the facilitator) may be close to the maximum. For some issues and some personalities, a group of eight will produce an "effective" group of four; for others a group of 20 might also produce an effective four.

It has turned out that the personalities of the players have had a role in the success of projects. This has been a bit disappointing to us. Steeped in system dynamics, we would prefer to believe that the structure of the group is the only important variable. Unfortunately it appears that there are people who take to this quite readily and those who don't. Those who have some difficulty are often strong operating managers with reputations for getting things done on a day to day basis. They often take a bottom-up approach to problem solving. Managers who are able to draw meaning and insight from the process tend to be reflective; strategic. They tend to take a top-down view of the business. Those strongly endowed with an operating or tactical viewpoint may be uncomfortable with the aggregation level of the model and with the accuracy of parameters and model results. The more reflective or strategic types focus instead on patterns of behavior and the relationships that can generate this behavior. The contrast can be quite striking with one manager discovering road blocks, while another uncovers deep meaning in a table function. A single team member can disrupt and delay a team if he or she remains uncomfortable with the methodology or the study deliverables (in our work, determinants of behavior, without emphasis on predictions). This has demonstrated to us the importance of focusing on the few critical team members necessary for model development and insight generation.

## IV. Positives and negatives

The positives of a system dynamics approach are often discussed. These positives -- including the ability to define critical processes affecting business performance, creating more effective mental models, discovering effective strategies or policies, and creating consensus -- are very real and very significant.. However, the negatives, which receive less attention, are also important to anticipate when launching system dynamics in an organization.

First, system dynamics is hard. Maybe not as hard as small particle physics, but still harder than, say, the BCG growth-share matrix of stars, dogs, and cash cows (Hax and Majluf 1984, pp. 127ff). And, system dynamics is harder than a casual reading of the Fifth Discipline might suggest. Eastman's experience is that the process is not well documented in publications. The process appears to require some knowledge of or feel for feedback control theory, a set of structural building blocks (gained from modeling experience or study of others' models), and an artistic or craftsman's sense of what works. Eastman has used external expert consultants to assist in moving up the learning curve.

Second, it is difficult to explain what system dynamics *is* and what the benefits of modeling will be. Many concepts are abstract (mental models, consensus, feedback) and not the sort of thing that managers realize they need. We frequently cite case histories to more clearly define the methodology and its benefits. The most effective case histories are the ones involving Eastman itself. We are writing up each project as a one-page "success story", capturing key learnings and benefits. But, success stories were necessarily sparse at first, and the presence of a highly respected advocate has been critical. Some budgetary discretion also has been extraordinarily valuable, to lower the "yes" threshold of potential clients.

Finally, time requirements are high. The system dynamics process, as we practice it, requires the key managers of a business. Time is a commodity in short supply for these managers. In a project that goes through a complete computer model, we generally occupy half a day to a day per week of each executive's time for the duration of the project. In terms of hours, the process that results in a causal loop or stock-and-flow diagram takes 8 to 12 hours of the project team. Developing a core model (two to four loops) takes 8 - 32 hours. Each increment to the model takes about 8 hours. And, policy analysis takes 8 to 80 hours. These are high demands on an executive's time. We are investigating processes for executing the process more quickly. However, significant managerial involvement will likely always be important if the benefits are to be achieved, and if system dynamics is to become an important part of Eastman's decision making process

## V. Path forward

We have devoted some thought to how to move forward from the present base. At this point several initiatives are underway.

**Education.** Education is key. First, we have defined nine feedback structures to study in order to sharpen skills and to serve as a mental library of building blocks for modeling. We are also studying classic models that demonstrate the system dynamics methodology and which are also relevant building blocks for future modeling efforts. For example, a key area of interest in the chemical industry is the movement of chemical products from specialty to commodity markets. Consequently, we are studying a "modern" version of Meadow's commodity model. Technology or market diffusion models such as Aaron (LeapTec 1993) are also relevant to the launch of new chemical products where pricing, investment, competitor response, and product improvement are all issues that need to be considered.

In addition to the internal team study, Eastman is scheduling regular training workshops with external experts in system dynamics. As mentioned earlier, we feel that personal exposure to experienced practitioners in the field is essential, because the discipline has an important artistic or craftsman component.

**Funding.** At this point we have defined funding needs for training and for acquiring necessary software and hardware. Funding is also needed to engage external experts for education and support. These funding needs will be met by a combination of the advocate's own budget and the financial support of groups with which we are doing projects. Eventually all the system dynamics efforts must be entirely funded by other groups within Eastman. This is necessary in order to demonstrate that Eastman managers as a group believe that system dynamics pays its own way. We anticipate the transition to total "outside" funding may take five years. However, we will track the proportion of funding coming from outside, and expect that it will rise steadily. The internal focus group maintains a list of potential and "backlog" projects. We hope these will provide a continuous stream of applications for learning and funding. The completed projects and our "backlog" represent issues in a variety of Eastman businesses, allowing a broad base of experience and contacts to be developed.

**Staffing.** There are two components of our staffing: internal and external. Eastman has gained considerably from outside experts and will continue to use experts for support and training. Currently Eastman's needs for outside support are in the initial definition stage of the system structure and in the final stage of model building and quality assurance.

Today there are nine members of the internal focus team. They are matrixed into the system dynamics effort, and have other responsibilities. Team members have a common interest in broad organizational issues, but different skills. Seven are practicing engineers with graduate degrees in electrical, chemical, civil or mechanical engineering. Two members are professionals trained and experienced in organizational behavior and small group facilitation.

## VI. Conclusion/Summary

A group of managers at Eastman has successfully launched system dynamics within their organization. System dynamics will be harder to master than perhaps the managers anticipated. The success of the initial projects, however, have also exceeded expectations. We hope that Eastman's experience with the launch will be helpful to other managers trying to get system dynamics underway at their own organizations. The next challenge is to develop the organizational structures and stories that will sustain a continuing system dynamics effort in the years to come. We hope to be able to report back in the not too distant future on how sustainability was achieved at Eastman..

**References**

Andersen, D. and G. Richardson. 1994. "Scripts for Group Model Building". Forthcoming in the Proceedings of the 1994 International System Dynamics Conference. Sterling, Scotland.

Godfrey, P. and L. Evans. 1992. *The Tale of Windfall Abbey.* Uxbridge, Middlesex: BP Exploration Operating Company Limited.

Hax, A. and N. Majluf. 1984. *Strategic Management: An Integrative Perspective.* Englewood Cliffs, NJ: Prentice-Hall, Inc.

Kauffman, D. 1980. *Systems 1: Introduction to Systems Thinking.* Minneapolis: Future Systems, Inc.

LeapTec. 1993. *Aaron.* Providence, RI: LeapTec.

Randers, J. 1980. *Elements of the System Dynamics Method.* Cambridge, Ma: M.I.T. Press.

Richardson, G and D. Anderson. 1994. "Teamwork in Group Model Building". Working Paper. Albany: The Nelson A. Rockefeller College of Public Affairs and Policy, State University of New York at Albany.

Richardson, G. and A. Pugh. 1981. *Introduction to System Dynamics Modeling with Dynamo.* Cambridge, Ma: MIT Press.

Richmond, B. 1991. "The Strategic Forum: From Vision to Strategy to Operating Policies and Back Again". Hanover, NH: High Performance Systems.