# SYSTEM DYNAMICS AND THE USER
## A View from the Trenches

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ABSTRACT

Practitioners of system dynamics working in the government sector will often operate in environments filled with administrative complexities and bureaucratic inconsistencies. Some examples of less than ideal conditions encountered in a fairly large policy planning effort are here offered for the student of system dynamics.

### Overview

The 1983 International System Dynamics Conference emphasized enlarging the paradigm, or consolidating it through improved quality, generic model development, and teaching. The discussants were practitioners and theorists well versed in system dynamics. But the advancement of SD must incorporate the needs of the user, as well as the skills of the expert. It would be a mistake to stress professionalism for the professionals and sacrifice utility for the user.

This paper discusses the realities of user demands as experienced in a research project funded by a major (U.S.)



274 government agency. A method for evaluating the 15 year fiscal needs of the agency was modeled, parameterized, and implemented. Many of the truly dynamic features of SD could not be used, causing frustration to the researchers, and perhaps even compromising their methodological principles. Yet today government managers using computer terminals adjust policy and configuration inputs, and obtain alternative fiscal budgets and system cahracteristics over the 15 year planning horizon. They conduct what-if drills in minutes, when they previously took weeks. Are they the "right" drills from the taxpayer's viewpoint? Probably not. But the results are better than the previous system's. A compromise evolved.

So, this paper is about how managers respond to other managers above them and to politics around them. It is about how accounting systems drive the needs of the user -- and if the accounting systems have inconvenient categories, then the model must change, the system won't. It is about disaggregation, and how users may demand subcategories (even when they contribute little to policy making) because the vocabulary of their organization so requires. It is about users biasing parameters to get more politically acceptable answers -- and about how parts of the model output are discarded while other parts are selectively retained. And it is about users who are not accessible when needed; who require that all model projections which differ from existing projections be

accounted for; who must satisfy bureaucratic stone throwers elsewhere in their organization that the results are completely valid or risk having the model discredited on a minor technicality. It is also about how top management (which could circumvent these problems) is not available, not until results are forthcoming. And it is about how valid and visible predictions may, for political reasons, be the last thing top management wants.

Users often require a model to be up and running quickly -- even incompletely -- before the funding dries up. Intangible concepts (such as "bias to underestimate costs" or "perception lags") are seldom acceptable, no matter how relevant they may be. Good graphics become crucial as do the marketing briefings to sell the model. And internal implementation may be demanded even before the receiving organization has the necessary hardware/software capabilities.

In that scenario, the rational, deliberate development of the paradigm becomes a remote goal. The "real world" seems too messy, too bureaucratic for such purity. But fortunately, system dynamics allows modeling in the real world of the user. That is its real strength. "The profession" must not avoid that fact in its search for improvement.





## The Project

In 1980, the Office of Naval Research agreed to fund an experimental effort in applying system dynamics toward predicting the longer range (15 year) fiscal needs of the U.S. Navy. The project was called "Navy Resource Dynamics," or NAVRESDYN. The fiscal problem was well suited to feedback analysis. A fiscally constrained organization annually developed a budget for the next relevant fiscal year, plus a program plan for the five years following -- a combination called the "Five Year Plan." The analysis beyond the five year horizon was very sketchy, well known as being unrealistic, and considered unimportant given the political facts of administration changeover. It was argued by the NAVRESDYN project personnel that the longer horizon was essential.

The dynamic aspects of the problem centered around the trade-off between procurement of systems (ships and aircraft) and the subsequent ownership (operating, maintenance, manning, support) costs of those systems. The fiscal constraints over the planning horizon caused a dynamic trade-off between any one year's procurements and the same year's ownership costs, the sum of which had to add up to fiscal guidance. As an admittedly oversimplified digression, the U.S. Navy, as well as every other federal agency, acts under this "fiscal guidance" mode. An agency does not determine the budget it needs to perform its mission; instead it determines what can be

accomplished within the fiscal levels dictated to it from a higher level, such as the President or the Congress. That may not seem rational to all, but it is the only workable way for a government to put a budget together.

The essence of the dynamics resided in the fact that the portion of the annual budget going toward procurement would contract for new systems that arrived in the fleet some five years later (about the time it takes to build a ship), while the ownership portion went toward operating fleet units accumulated over the previous thirty years. With the emphasis on the five year plan, it was quite likely that a buildup such as that proposed by President Reagan could lead to fleets not supportable a decade later. This question of fiscal affordability in the future, made today's procurement decisions crucial, considering the thirty year life span of ships and the fifteen year lives of naval aircraft.

Figure 1 provides a simplified diagram of the annual budget model. The logic used dictated that the existing fleet would be given its necessary ownership costs, and the remaining budget available each year would procure new units and pay research and development costs. This was almost opposite to the prevailing planning methods, in which the desired fleet procurements were costed out, and then the remainder of the budget allocated to ownership. That logic had led to a



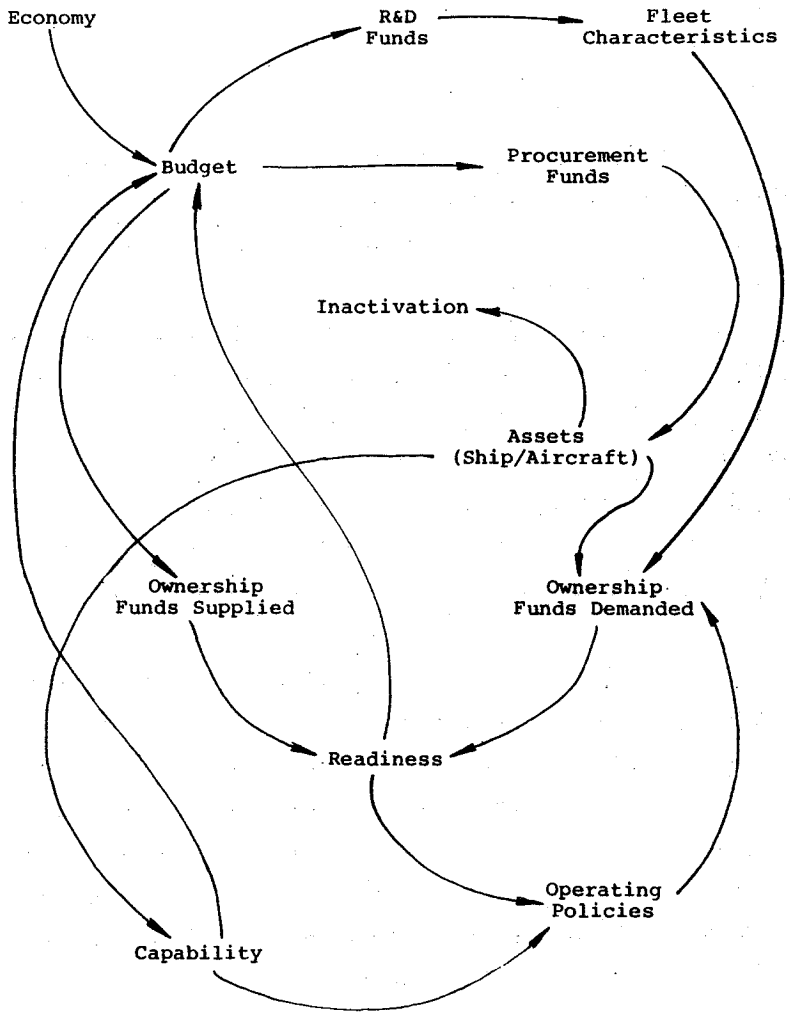


Figure 1. Simplified Navy resource dynamics structure.

virtual necessity, each year, to reduce previous procurement plans, and increase ownership budget -- for Navy planners were biased toward overplanning procurements, which meant underfunding ownership. It was the annual reallocation to correct for the planning errors that caused instability. The instability in turn caused unit cost growth as contractors revised production schedules, and so on. NAVRESDYN personnel argued that better planning would lead to less instability, and to a net gain in force effectiveness for the same funding levels.

The model is more fully described elsewhere.[1] Here we are interested in the modeler/user interface.

## The User

It is too easy to fall into the trap of saying "the Navy." The internal decisions, the planning process of "the Navy" involves hundreds of people and dozens of major organizations. Yes, eventually there is a five year plan signed out by the Secretary of the Navy, but putting that plan together is a process involving thousands of memoranda, briefings, telephone calls, and meetings between hundreds of people. To have any impact on the eventual outcome, one must obtain the support of one of the decision makers in that

[1]See "Extended Planning in the Navy and the Resource Dynamics Project," Clark, Graves, Sheehan, 1983 International System Dynamics Proceedings, Vol. I, pp. 397-408.



process. The decision makers, usually Vice Admirals or higher, determine how available funds will be allocated. To gain their support usually means dealing with staff personnel two or three organizational levels below the decision makers -- for that is where the justifications for resource decisions evolve. A Naval officer of middle rank (say a commander) on a two year tour in the Pentagon will have the task of assembling the briefings and background papers for decisions on the funding needed, for example, for ship maintenance. These middle managers are crucial in the process. They have the facts, which have been assembled through data calls, phone conversations, and briefings from numerous sources throughout the 750,000 person Navy. These "action officers" work long days at a furious pace to meet deadlines. The decisions of the policy makers rest largely on the ability of the action officers to decipher the volumes of input into a usefully condensed set of briefing charts.

One of the points to be made here is that in such large organizations, the typical researcher does not work with "top management," but with these middle managers who respond to others in the system. The concept that system dynamics, being a policy tool, is best done when "the decision maker" uses it is valid, and correctly taught in the academic world. It is not, except for the few very well established practitioners, a luxury to which many of us are privy.

A second point to be made is that large organizations like the Navy have need for system dynamics, even if "top management" does not support dynamic planning. System dynamics may be most needed in such an environment. If impacts are to be made in federal policy areas, they will usually come from within the organization, not from an attack from outside. If the top policy maker does not support SD, we should struggle on anyway. It would be irresponsible to abandon an effort to improve government efficiency simply because the administrative details become too uncomfortable.

It might be argued -- probably with much validity -- that in a profit making organization (as opposed to a fiscally constrained government agency), many of the problems of implementation about to be discussed would not occur. If SD indeed enhanced efficiency then top management would adopt it. Meanwhile, the "turf battles" and "pork barrels" of bureaucratic organizations without a bottom line profit motive often derail efficiency in policy making. Yet an agency like the U.S. Navy has an annual budget approaching 100 billion dollars. The SD community can hardly ignore the need to help in that arena, despite the messiness of operating therein.

## The Specifics

What are some of the differences between university taught system dynamics and the messy environment of real





world practice? The following are a few examples.

First is this matter of not dealing with top management. When modelers coordinate with middle management, inconveniences occur. Meetings scheduled with higher level managers are cancelled 15 minutes before they are to begin. Their rescheduling can require a dozen calls to participants to determine their next availability. Persons assigned to be on the modeling team find reasons for not appearing or sending an uninformed substitute in their place. The determination of such project personnel may have required a series of memoranda requesting names, and a related series of briefings on why the participation of someone from each organizational sector is needed in the first place. Whatever organization the modelers are working with will no doubt appear to be covering some part of another organization's responsibility (the turf battle part). And for a project of this type, findings that some part of the budget seems too large will cause strong reaction from some other policy maker (the pork barrel part). A resulting set of briefings to explain the logic to organizational antagonists is scheduled (again with scheduling difficulty). Each point made by project personnel will be countered and questioned, often based on an adversarial argument rather than on unbiased rationale.

None of these problems would result if "top management" were involved. Everyone would support the effort (at least more fully). Does the student of SD really want to become involved with such problems? It's a good question.

One of the most frustrating factors in the NAVRESDYN project was the difficulty of having those in decision making positions take interest in the resource problems beyond the five year plan. The political process was in cadence with the life span of the administration, which was captive to elections each four years. The most long range document prepared for discussions with Congress was the five year plan. Jobs and reputations hinged on that time frame, not on the 15 year horizon. In fact, those who pressed too hard for the longer range views were often not taken seriously, since even the five year plan was such a changeable thing from year to year. Arguments that the five year plan could be improved if the longer term was considered were not given much credibility, for they could not be proven. Again, the lack of a profit motive meant long term efficiency was far less crucial than short term marketability. The rapid turnover of senior managers within the organization meant (to them) that "the long term" simply would help their replacements. This may seem distressing to purists, but it is a fact well known to practicing system dynamicists. Imagine a politician trying to convince the public that doing away with food stamps will





cause less need for them ten years hence. It may be true, but it would be hard to blame a representative for not making that part of her election campaign.

In another direction, there was frustration in this project in the form of disaggregation. While almost all of the important dynamic trade-offs might have been derived from a model of 100 equations, the known accounting systems, manpower systems, and force inventory methods dictated the 100 equations be expanded into a disaggregate model of 2,000 equations. Naval officers were not willing to plan in terms of "combat aircraft," ... they were used to speaking of F/A-18's, F-14's, A-6's, etc. Budgeteers did not speak of "maintenance," but of organizational level maintenance, intermediate replenishment spares, depot level replenishment spares, and so on. The model had to speak in the same terms to gain a listening audience. Statistical data bases had to become more detailed to allow the disaggregation. Little was contributed to policy making, but organizational vocabulary was met. It would be a mistake to think such organizational definitions can be overcome. For starters, data are maintained by the organization in established organizational categories, not in those convenient to the modeler. The model must fit the system; the system will not change. We accordingly crammed our 100 equations into 2,000 lines of code. Accuracy

did improve slightly, and the model was more marketable. Not unimportant factors.

Predictably, once the model began producing results users became selective in the parts they utilized. If maintenance needs were expanding while fuel efficiency was allowing reduced demands for fuel, one user might highlight the former result, and ignore the latter by criticizing relevant model assumptions. The fuel predictions might instead be derived from some other part of the organization. The time phased effects might also be treated selectively, with short term budget needs stressed while long term counter trends might be ignored. One could ask how honest researchers could allow such misuse. The answer is the models were being developed for the users, with their money. The researchers could encourage analytic completeness, but the users would use the results as they deemed best. Probably it should not be any other way; after all, opponents to the user's views were developing their own prediction tools, equally biased. Most justice systems are founded on the same advocacy basis -- the prosecution seldom is objective, nor is the defense. Nonetheless such tactics are frustrating to the student of system dynamics.

Several problems arose with disaggregation -- at least in the often adversarial arenas in which model projections





were discussed. First, while the policy level model could be quite valid for the time period of interest in the future, the model's projections for the first year or two often varied considerably from the actual budgets the Navy was submitting. To make the model match exactly in the short term would require building in as much detail as is involved in the budget itself ... obviously not the intent of the SD approach. As long term results are not usually affected by the first one or two years, modelers can do some selective analysis of their own, and simply calibrate the initial conditions and parameters to fit initial trends. It is better, however, to avoid any predictions for the short term, if the user lets one get away with that. In NAVRESDYN, we explained why initial differences should be expected, and then emphasized the time period beyond three years.

Disaggregation also led to attempts at model rejection by those who could lose funding. One ship (of 600) put into the wrong bin once caused claims of invalidity. If the model is aggregated such specific details do not emerge. Disaggregating to the categories required by an accountant in one part of the organization leave the model results open to comparison by someone else with detailed data in another part. Yet the policy implications of being off by one ship one year are negligible. But the argument that "it is only one ship"

was countered with "that one ship costs 800 million dollars." It seems hard to call that insignificant.

Directly opposed to the attempt to deliver a valid model is the fact that users want the results soon. The researcher wishing to be funded next year had best deliver a model when needed. In our case, we had results in six weeks, caveated heavily with "this is approximate." We knew, though, that we would be stuck with those numbers to defend at every point. The irony really lies in the fact that funding for the project had been provided by the user from an analysis budget, but the time lag from their agreement to fund us until a contract was signed was six months! Yet, as far as the user was concerned, the project was underway as soon as funding was made available. When would they get results? So researchers worked on their own time to get a model up and running quickly, a model which would be criticized because full statistical analyses had not been completed. Small wonder that a ship or two would be out of phase given the rush to be responsive.

In working with this user, we found a general irreverence for "intangibles." Intangibles, we know, are what enrich the model and allow effective examination of policy impacts. But selling the user on such psychological abstracts as "bias to underestimate costs" or "maintenance backlog perception lags" were not acceptable, no matter how relevant. The modeler, knowing these must be included to capture the system under study, may (after some experience) simply forget to advise the user that such factors are buried in the equations. In this particular effort, one astute naval officer advised the modelers to model it, but not to advertise it. How was anyone going to admit to the Secretary, he asked, that we knew we had a bias to underestimate costs and were adjusting accordingly? We finally included switches which allowed the bias to be turned on or off, and could run it both ways. The "no bias" version was inevitably selected by the user, while in our own analyses we would turn the bias switches on.

One user need expected by the SD team was the request for graphics. Briefings for senior managers were frequent and often unscheduled, so briefing charts discussing the project and the model predictions were essential. This marketing aspect is a very important factor, and one that SD is well geared for. Related to graphics was the fact that senior managers demanded -- or at least their administrative assistants demanded -- that any written correspondence about the findings be reduced to one page, with one or two graphs if necessary. This condensation process is very healthy for project purposes. It forces a focusing of the issues being highlighted. It was essential that graphics be as uncomplicated as possible so that viewers seeing the techniques for the first time could track the results.

Graphics can backfire, of course. We once ran into difficulties by not carefully scrutinizing the managerial schedule called for by Navy users. Our project was required to produce predictions of the average age of aircraft prior to a certain date. We had done so for two years, basing our predictions on data received from a branch of the Navy responsible for keeping data on Naval aircraft inventories. It turned out that the data provided by our project had been produced with such clarity that the organization responsible for providing our raw data had decided that they no longer needed to produce any data, given our report was so graphically superior. A good system dynamicist would have foreseen such feedback effects. It took considerable effort to get the organization involved to keep producing the raw data, and to do so before our own deadline passed.

The largest blow to the project came, however, from its own success. Once the dynamics were modeled, and the statistical studies backing up the model completed, predictions of Navy resource needs began to evolve. The predictions far into the future were suddenly not only available, but quite persuasive in their logic. One would think that a good result. But it caused problems for top management in two ways. First, it made visible, perhaps far too visible, the long term resource needs of the Navy. Managers became fearful that such visibility would lead to an opening of Pandora's box, and let



every critic of Navy policy choose portions of the predictions for attack. The Navy would spend much time countering such selective attacks, which could not have occurred had no predictions been available.

The second problem arose from the strength of the model to conduct rapid "what-if" drills -- usually a desirable feature. One user, acting on the rumor that Congress might cut the military budget by 10%, asked for a computer run of the impact such a reduction would have on fleet levels. As soon as the run was made and the results presented, there was concern at higher levels that the press would report that the Navy had made plans based on a 10% budget cut -- and if they had planned for it, it must be feasible. Seeing the problem, we suggested that the user have us conduct excursions not only at -10%, but also at +10%, -5%, +5%, -1%, and +1% ... thereby flooding the press with many options and not highlighting any one in particular. Unfortunately, the time lag between top management's initial concerns and the feedback of the suggestion was too long, and the project was jeopardized in the interim.

## Conclusion

The question arises whether it is worth working in such an environment. The answer seems to be an affirmative -- and not only because the research team needs to remain employed.

For while most government problems must be approached in similar complicated circumstances, government problems are the ones that affect our society the most. No matter how administratively difficult, increased governmental efficiency is worth working on. With agency budgets in the billions, with no profit motive to force efficiency, the system dynamics community is obliged to provide perspective in such areas.

Did the Navy Resource Dynamics project produce results? Yes, not dramatic, but certainly significant. At the minimum, a planning process that once took over 20 people several weeks (including weekends) to accomplish was now being done by two people in about six hours spread over three days. We had automated a manual process. But much more evolved. While it is hard to claim full credit, the project did provide information to other policy makers inside the organization, which helped in at least two ways. First, the data accumulated and the trends developed provided convincing evidence that unit costs for certain systems were being estimated at levels higher than that justified by the facts. Over one six month period, cost estimates for Naval ships were lowered considerably from earlier demands allowing procurement budgets to be reduced. Reductions of any magnitude when procurement budgets reach thirty billion dollars a year are significant.

Second, certain ownership budget areas were highlighted as being too large by as much as 10%. This did not cause budget reductions, but did influence planners to stop pressuring for increasing readiness funds, and to begin considering decreasing them. Helping to cause a change in the direction of pressure is not so dramatic as causing an immediate multi-million dollar reduction, but it is a significant result nevertheless.

The governing process is changed by such shifts in perception. They occur from within. That is where system dynamics is needed, but that also is where the environment is very messy. Successfully impacting the system may mean that unpopular insights will be highlighted. And that in turn may mean (as it has for our project) losing support for future efforts ... the Navy has decided to bring the Navy Resource Dynamics model in-house. But that is as it should be. The real value of system dynamics is that the important insights developed to not die. The enlightenment was catchy, and there will remain advocates within the system in favor of understanding the full dynamics ... they will keep the methods alive. The system will improve.