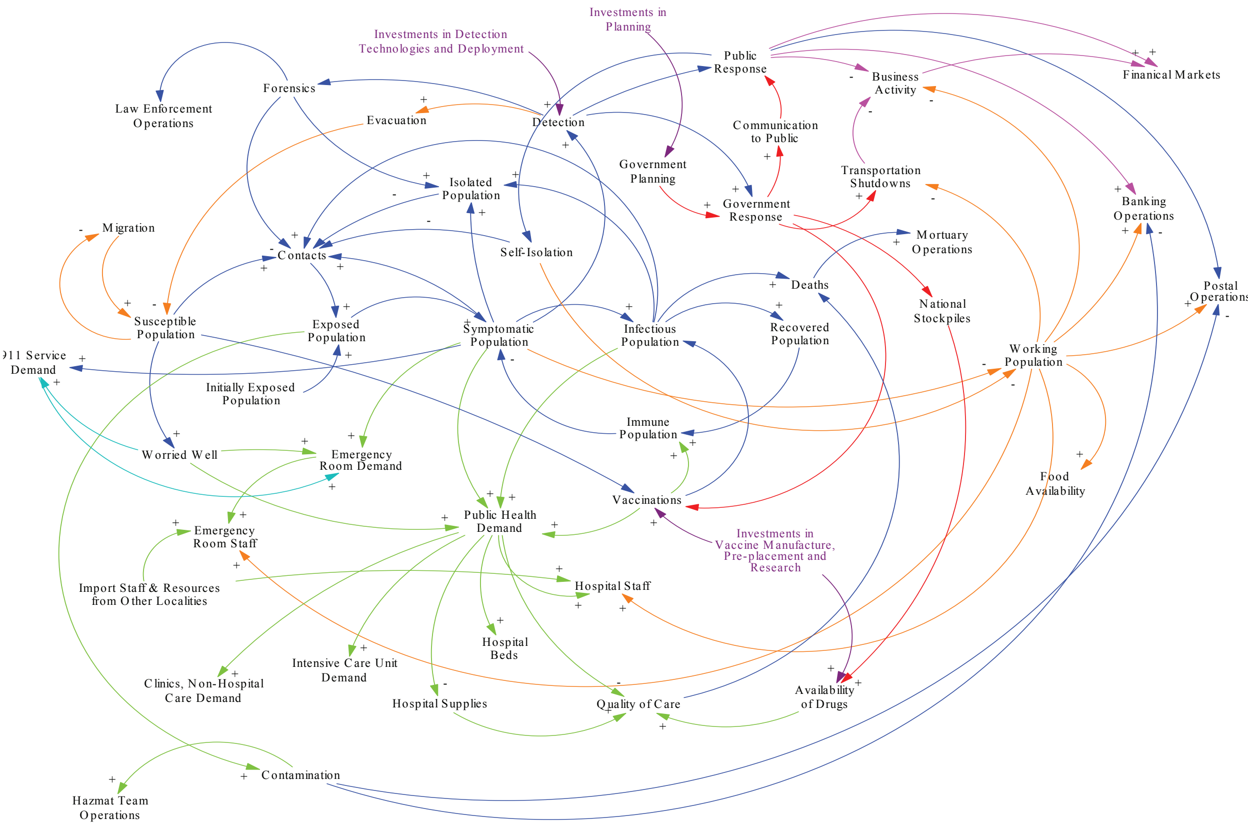
TAKING ACTION: LOOKING BEFORE WE LEAP

BY BRAD HOLTZ, CHIEF STRATEGY OFFICER, CENTER FOR UNDERSTANDING CHANGE (C4UC)



The purpose of the Global Action Summit is to explore the big and complex problems of Food, Health, and Prosperity. Much of the output of the summit centers on proposed means to address these key challenges. Unfortunately, we are ill-equipped to understand the efficacy of these solutions. We need to be better informed of the likelihood that our actions will achieve the desired results AND the impact our actions have on areas outside our expectations.

System Dynamics models are an effective tool for getting a better understanding of complex, interdependent systems. But it's not enough to model the domains we know. We need to create models with a broader perspective than any one organization or group can achieve on its own. We need to combine our resources to model and explore that broader perspective. Unfortunately, much of our own deep knowledge of our own domains is proprietary or sensitive, blocking our ability to combine resources for the bigger picture.

The Center for Understanding Change (C4UC) has developed a set of tools and methodology to get around this challenge. This article details the nature of the problem and the C4UC solution. It is our hope that we will be able to use this to deliver a better understanding of the implications of proposed actions suggested at the Global Action Summit.

Center for Understanding Change (C4UC): A System Dynamics Model

Example of interdependencies diagram for a Flu epidemic system dynamic model. From the US Critical Infrastructure Protection Decision Support System (CIPDSS) a set of SD models built with a common set of semantics, with 4482 variables across 18 critical infrastructures, including Agriculture & Food; Healthcare & Public Health; and Banking & Finance, among others. CIPDSS is a joint effort of Sandia National Labs, Los Alamos National Lab, and Argonne National Lab, originally underwritten by Department of Homeland Security. CIPDSS was the inspiration for the founding of the Center for Understanding Change.

WE FACE BIG AND COMPLEX PROBLEMS

Food, Health, and Prosperity are complex and highly interdependent issues. When we make decisions that impact prosperity, we also influence food and health, and vice-versa. And other areas as well. That's the nature of our complex world.

Each of us has an impact on our complex world. We make decisions and act (or fail to act), and we use our influence to change the way others (individuals, groups, corporations, or governments) act. These decisions, action/inaction, and influence are the tools that we have at our disposal. We use these tools individually, and sometimes in coordination with others. But we are often indiscriminate with the type of tools we use -- we can use scalpels or blunt instruments.

WE RISK THE RESULTS OF UNINFORMED DECISIONS

All too often, when concerned about trends or issues, people (and groups/politicians/etc.) look at problems in isolation, without the broader context. This leads to answers or calls for actions which are overly simplistic. And when these actions/decisions are implemented, they inevitably achieve undesired results and unexpected new challenges occur.

There are a number of global trends that will impose change on us (urbanization, nanotechnology, climate change, globalization, social media, etc.). ***We need to think of these trends as having mass and momentum.*** That way we can better understand how the idea of leverage applies to trends: Given enough time, we can apply small forces to affect needed change. Unfortunately, we don't pay attention to trends until we're beyond the point where small actions will fix the problem.

Our actions have momentum as well. Once imposed, changing them is difficult, particularly when that action is legislated or embedded into regulations or public policy – even when the demand for action has shifted. We often encounter three scenarios with regard to trends.

1. "Do Something!"
The first challenge is when a trend captures the public attention, to the point where there is a public outcry to "DO SOMETHING!" Often when this occurs, the actions called for are blunt tools and have undesirable side-effects. And the actions called for will not fix the problem – in many cases they exacerbate the problem.

2. "Can't afford it now"
A second challenge is lack of support for a needed action when the threat seems to be far away. The need is pressing but distant, either due to lack of visibility, understanding of importance, or distant time-horizon, generating resistance to allocating appropriate resources. Sometimes we can see that a trend is going to result in a significant threat and that we could take small actions now to address the threat. The challenge is that often those actions come at a cost we're not willing to bear at the moment, because the threat is so distant. The resistance to allocating small resources now, pushes the problem down the road, when the costs and challenges will be disproportionately more difficult.

3. "Right Solution, Wrong Problem"
The third challenge is operating with an incomplete understanding of the problem. Even when proposed actions are well designed to achieve the intended goals, the design, exploration, and even testing of theory (if it's done at all) takes place within a limited context and as a result, ignores impact beyond the limited context. Often this results in local optimization at the expense of global optimization, but more critically, it allows the deployment of actions without considering the broader implications.

ANTICIPATING OUTCOMES BEFORE WE ACT

We need to act more wisely if we are going to avoid these scenarios. In order to "Act Wisely," we need broader thinking: understanding the larger context, exploring the longer-term consequences, building in feedback mechanisms, and testing our theories…before we act.

Modeling and simulation tools help us explore the implications of our proposed actions. It's not that we aren't already building models; it's that we need to explore interdependencies across a much broader context. When we do that we can explore uncertainties, and understand sensitivities to our assumptions. And we can test our theories, watching the impact evolve over time, and design-in feedback mechanisms so our actions don't run amok after achieving their goals.

What is needed is a better understanding of the relationship between correlation and causality for these complex systems. And we know how to do this. We create models to help us understand how things work.

The Center for Understanding Change (C4UC) is a 501c3 non-profit that builds tools and methodologies to facilitate bringing groups of stakeholders to a common understanding of their complex issues. Specifically, C4UC helps decision-makers come to a better understanding of the implications of the choices they have in front of them.

Key to achieving this, is solving the challenge of getting groups with differing interests to combine their independent research and data on the issue at hand. This is tricky, given that such knowledge is often proprietary and sensitive – sharing, or even just the risk of exposure to competitors, just can't happen. This is the "stakeholder problem," and C4UC has developed a software solution that solves this problem for types of issues that can be modeled with System Dynamics (SD) models.

SYSTEM DYNAMICS MODELS HELP US UNDERSTAND

SD models are used extensively throughout the public and private sector for policy analysis. One of the key features of SD modeling is its ability to handle the non-linearities of feedback loops, which is part of the reason why we use SD models to help us understand the behavior of complex systems over time.

THE STAKEHOLDER PROBLEM

Think of Coke, Pepsi, and NIH trying to work together to explore health impact of sugar and sugar substitutes. All three have a vested interest in the outcome and all are working towards a common understanding of the bigger picture. And all three have their own, internal, highly confidential models and data that are critical to understanding the bigger picture. But there is no way that either Coke or Pepsi would be willing to expose their secret corporate data to the other. And NIH has its own issues with HIPAA compliance. That's the stakeholder problem, in a nutshell.

C4UC has developed a framework that solves the stakeholder problem for SD models. The framework currently allows SD models and data from tightly constrained sources (including both stakeholders and others) to interact in a manner that requires neither the model, nor its supporting data to be exposed outside of the owner's environment.

The net result of this is to allow the application of a richer and more complete set of models to a proposed problem. In other words, the stakeholders can combine their models and data to create what you might call a "supermodel" and they can do so without the fear or risk of exposing their proprietary or sensitive data.

This framework also is the underpinnings of a solution that can, with further funding, also allow SD models to interact with actor-based models (also known as agent-based), financial models, network models, and eventually, weather models.

In order to best understand the bigger picture we need access to the SD models and data held by stakeholders. The challenge is that each stakeholder has a limited view of the internal workings of other stakeholders. In their models, they must make critical assumptions about other stakeholders.

A NEED TO SHARE OUR MODELS AND COMBINE OUR DATA

What we really would like is to combine the models and data from all stakeholders (and other resources), all rolled up into a larger "supermodel." This "supermodel" is key to understanding the complexities of our decisions, and to exploring the implications of our theories and proposed solutions. However, combining SD models has its own challenges.

This idea of combining models (and data) from the many stakeholders has three key challenges:

• ***The first challenge is that we need to align the science of the models, addressing syntax, parameters, assumptions, relevance and reasoning and other understandings.*** This will require that the scientists who created the models in the first place must talk with one another and collaborate, even if they can't share the proprietary details.

• ***The second challenge is one of software and technical complexities.*** We'd like to have SD models interacting with agent-based models and networks models, but that isn't possible with current tools. And even when working with the same types of tools, there are interoperability issues among software tools, and even when working with the same software tools, combining models often requires adding content from one model into another, larger model.

• ***This last aspect would not be so challenging if it was not for the third challenge: stakeholder reluctance to share their models and data.***

THE SHARING PROBLEM

Combining models is a complex challenge… it's not so easy...but it's not impossible.

We need new ways to understand our rapidly evolving world and to explore the implications of planned actions and the risks and opportunities these actions present. A key challenge with leveraging these tools for large-scale exploration is that, while much has been invested by many parties in developing these models, independent efforts have resulted in models that either can't interact with one another due to technical issues, or aren't allowed to interact with one another due to internal (political, IP, security, etc.) issues. And when it comes time to explore the models, data is even more problematic.

The task is solvable. The Center for Understanding Change (C4UC) is dedicated to facilitate and explore these "supermodels" in the public interest. To further this, we've developed breakthrough technology and methodology that have allowed us to create a path to address the latter two issues: technical complexities and stakeholder reluctance.

We found a solution that fixes the problem. Today we can combine the models and data from many stakeholders, and we can do so in a way that treats each stakeholder's resources like a black box, with data and algorithms never leaving the stakeholder's firewalls.

There are several steps to building solutions. The first is to understanding what data is relevant and available. What SD models apply to the questions at hand? Who owns/controls those models and what state are they in? What is missing (both data and models)? Who are the stakeholders involved and what are their motivations? With this information at hand, we can explore areas where interest in coming to a solution is possible.

The real questions are twofold: What are we willing to invest the time in to explore the implications of? And, will we be able to act on the information we discover? If the answer is no to either, then why bother with the effort? On the other hand, if we are open to the possibility that public calls for simplistic, understandable responses to complex issues which are likely to get us in even more trouble, then we can use the SD models as tools to help the public understand the need for more complex, finer tuned responses.

C4UC has been working on its solution for three years. This past April 2014 was the first public demonstration of the software portion of its solution. In that demonstration, C4UC solved a well-known SD model, which was split into three different models and run on three different computers with different operation systems. Our demo succeeded. The combined results from the three split models were exactly the same as the solution of the unsplit model.

CALL TO ACTION: A SOLUTION FOR INTELLIGENT DECISIONS

We are now ready to take on our first pilot project. We are looking for a collaboration partner with an active challenge. The challenge should be one that could benefit by 3-6 months of active investigation – in other words, one where a firm action is not immediate. And it should be one that warrants the funding necessary to get that better understanding. It is our hope that we can jointly choose a key challenge to explore at the 2014 Global Action Summit and at the 2015 Global Action Summit to show our results, including a tool to allow audience exploration of the challenge super model we create.

C4UC STORY:
CREATING A REAL-TIME DECISION SPACE

The Department of Homeland Security funded a $60M+ joint effort of three national labs – Sandia National Labs, Los Alamos National Lab, and Argonne National Lab – to create a set of System Dynamics (SD) models designed to explore the implications of a major event on our national infrastructure – including an event natural or manmade, accidental or intentional, earthquake, hurricane, industrial accident, terrorist attack, etc. The set of models, the Critical Infrastructure Protection Decision Support System (CIPDSS) was built with a common set of semantics, with 4482 variables across the 18 critical infrastructures (including Agriculture & Food; Healthcare & Public Health; and Banking & Finance, among others). This set of models is used reactively, to understand the implications of a major event or incident.

In 2011, this project was the inspiration for the founding of a non-profit organization, The Center for Understanding Change (C4UC). It was our intent to work with the national labs to exercise CIPDSS proactively, to explore the potential implications of key decisions. While we have been successful in developing partnerships with the labs, the key challenge we ran into was that we needed to find a way to combine the CIPDSS models with the models held by others. In other words, we ran right smack into the stakeholder problem.

CENTER FOR UNDERSTANDING CHANGE (C4UC) USES SYSTEM DYNAMICS (SD) MODELS WHICH ARE TIGHTLY INTERCONNECTED AND INTERDEPENDENT. THESE LOOSELY INTERCONNECTED MODELS CAN BE SOLVED INDEPENDENTLY AND THEN LATER COMBINED. SD MODELS HAVE ORDER OF OPERATIONS DEPENDENCIES THAT MAKE IT NECESSARY FOR THE MODELS TO ESSENTIALLY BE SOLVED TOGETHER, AS ONE BIG MODEL.

C4UC's founders come from the software development industry and had access to a unique toolkit that seemed to be a perfect fit to the problem faced. C4UC spent the next three years (pulling money out of our own pockets) developing a path and software solution to the stakeholder problem for SD models.

Like most analysis software tools, SD software consists of three parts: "Pre-, Solver, and Post-." The first part of the software is where the model is set up, the relationships are built, the parameters set, and the data is linked or attached. Once set up, the second part—a solver—is run. Often the solver is run many times, with slight variations in assumptions/variables or with different data sets. Once the solver has completed, the third part of the software is used to explore the resulting solution set.

The C4UC solution is a solver. It can take the output of the Pre- stage from many stakeholders, and combine the models into a single "supermodel," and it does so without the risk of exposing the contents of any of stakeholders models. The output from running "supermodel" can be viewed with most any commercial data exploration tool.

In the C4UC solution, all of the math, algorithms, and data reside on a computer behind each stakeholder's firewall. None of that sensitive information leaves the company's firewall.

What does happen is that the parties work together to build a "skeleton" of a System Dynamics (SD) model of the big picture. This skeleton then drives an interactive "conversation" among the various stakeholder models. Each stakeholder model is passed only the information necessary to process to get the desired variable(s) for that part of the process. Only the resulting variable(s) is returned information down the line. The net result is that the only thing that is passed outside the owner's environment at each time-step is information that has been affected by the stakeholder data and model, not the data or model itself.

What enables this solution and framework is the groundbreaking work of Mike Riddle. Mike Riddle was the original author of what became AutoCAD and one of the founders of Autodesk. In 2000, at the industry forum COFES, (The Congress on the Future of Engineering Software), Mike posed the question: *"The software construction tools we have today were built based on hardware assumptions from the 1970's and 80's. Why are we still constrained by those assumptions when the hardware has evolved so much since then?"* Mike spent the next dozen years rethinking and building a programmers toolkit. His highly encapsulated, message centric system operates much more in line with Alan Kay's original vision for "object-based" programming than the "object-oriented" systems of today.

It is the messaging capabilities of the toolkit that give the C4UC solution the ability to combine individual stakeholder models into a single, "supermodel," even when the component stakeholder models are on separate networks, on different operating systems, and behind firewalls.

One interesting side effect of this new platform is that the C4UC solver is 30-100x faster at solving models than its predecessors. (And we expect to improve on that as well). But for many of the models we deal with, it doesn't take that long to solve these models in the first place. ***So why does the speed matter?***

It matters in two key ways. One, is that we can solve the model in real-time, as an investigator turns the dials on one or more variables, we can show the impact of the change without any noticeable delay, allowing for highly interactive exploration of the space.

Two, we can automatically massively explore the decision-space; understand the implications of sensitivity to assumptions; and run Monte Carlo and other stochastic explorations of the model, which can entail of thousands of runs, each run slightly modifying the variables, data, or assumptions.

WHAT ABOUT BIG DATA?

"Big data" is a term applied to massive sets of loosely linked data that are not constrained to standard data structures, where the aggregation of such data is difficult to process by traditional databases. The promise of big data lies in value of correlating aspects of the data and finding inferences and insight.

System Dynamics (SD) models include data. How much data and what level of granularity of the data really depends on the subject at hand. Validation and verification of the assumptions and fit of aspects of the model also require data. SD models are agnostic to where the data resides, as long as the data is available at runtime.

The link between big data and SD models is interesting. Given enough data and granularity (particularly historical data), it may be possible for big data systems to derive or fine tune the formula applied to any two components of an SD model. On the other hand, big data is NOT required in order to understand the bigger picture. (But it sure doesn't hurt.)

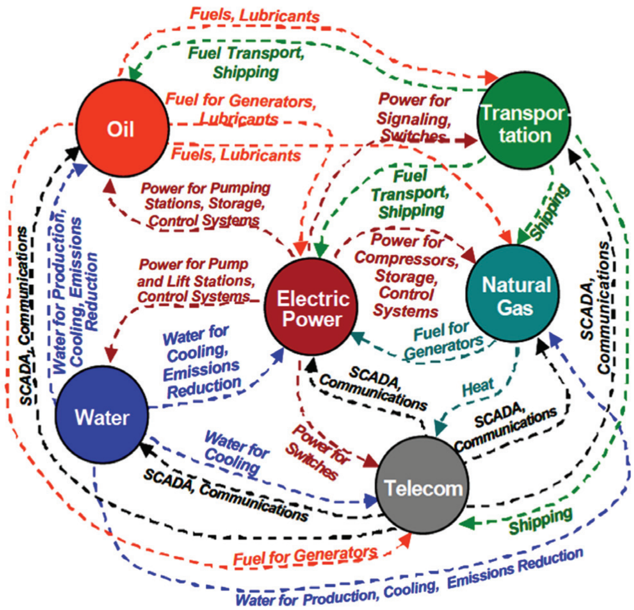
There is no reason SD models can't tie into both historical and real-time data. From the stand point of the SD model, what we're doing is looking at how variables change over time. We try to get our SD models to fit historical data (or at least explain the discrepancies) and then project what is likely to occur moving forward. Real-time data just moves that jumping off point further ahead.

When combining models to create a supermodel, some of the data required by the supermodel is likely to be readily available, either in the public domain or for purchase. Some will be data held by the stakeholders, and some is likely to need to be acquired/created/researched. Of the data in this latter category, some may need to be acquired/create/researched by a single stakeholder who will then keep that data as proprietary. Others may be shared among the supermodel team, or put in the public domain.

SD models are used to explore specific questions/situations. The idea of building a single, global model of the world for everything, is noble and valuable, but misguided. We'd all love to have Hari Seldon's Prime Radiant, but aside from the fact that the idea is itself flawed, we're nowhere near to having the tools necessary. Bob Bishop's International Center for Earth Simulation is doing a great job on some aspects of massive data exploration applied to the oceans and weather. And Kevin Montgomery's Collaborate.org is a tremendous resource for collaborative exploration of many types of collocated data.

What C4UC can do today and what makes sense for the foreseeable future, is to apply SD models to specific, hard challenges allowing decision-makers the foresight of understanding of what is likely to happen if they apply the solutions they are considering, and how likely things are to go wrong if certain assumptions are just slightly off base. We can do this for decision-makers who don't happen to be scientists or have a scientific bent – and we can also do this for decisions where there are many stakeholders with conflicting interests.

So the real questions are: Which actions are you facing that should really be explored more thoroughly before moving forward? Which are the decisions you face that deserve dedicating resources and investment in order to reach a better understanding of the potential implications of those decisions? ■



Interdepence Model: Water, Power, Oil, Transportation Telecommunications and Natural Gas

A DECISION SUPPORT "SUPERMODEL":

SD models are tightly interconnected and interdependent. While Loosely interconnected models can be solved independently and then later combined, SD models have dependencies that make in necessary to solve all of the equations simultaneously, as one big model. In C4UC's solution, before the actual processing of data, there is an exploration of the model skeleton and components that exposes the interdependencies of these simultaneous equations, resulting in a definition of the "order of solution" for the "supermodel".

Variables for the Critical Infrastructure Protection Decision Support System (CIPDSS)* modeler have already been developed across 18 critical infrastructures including: Agriculture and Food; Banking; Chemical; Commercial Infrastructure; Communication; Critical Manufacturing; Dams; Defense Industrial Base; Emergency Services; Energy; Government Facilities; Healthcare and Public Health; Information Technology; National Monuments; Nuclear Reactors; Postal and Shipping; Transportation Systems; and Water.

C4UC has other tools in place that prevent "back-probing" of the stakeholder model/data in attempts to derive its details. Part of this involves exposing to the stakeholder a human-readable text version of what crosses the firewall (allowing a "trust but verify" view). And part involves stakeholder control of what crosses the firewall in terms of frequency, range, precision, etc.

C4UC's intent is to leverage the framework for other solvers on, in order to broaden the range of models that can be combined. C4UC's current solution solver works for most SD models built with VENSIM (from Ventana Systems Inc.), the COTS SD modeling tool used to create the CIPDSS set of SD models. C4UC plans to work with others to enable the use of its framework for other solvers and modelers. C4UC's next software project is to apply its framework to a COTS or open-source Agent-based modeling solver. Others have committed to apply the framework to financial models.

** CIPDSS is now a part of the National Infrastructure Simulation and Analysis Center.*

BRAD HOLTZ is the founder for the Center for Understanding Change (C4UC), and CEO of Cyon Research Corporation. Mr. Holtz is the driving force for COFES, The Congress on the Future of Engineering Software, a leading technology event for engineering software. He is an advocate of technology, the environment and science to understand the impact of global changes and risk to critical infrastructure through research. Brad holds a Bachelor of Arts in Biology from Washington University (St. Louis) and a Bachelor of Architecture from the University of Maryland.