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The Joint Program Dilemma: Analyzing the Pervasive Role That Social Dilemmas Play in Undermining Acquisition Success

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Preface & Acknowledgements

Welcome to our Tenth Annual Acquisition Research Symposium! We regret that this year it will be a “paper only” event. The double whammy of sequestration and a continuing resolution, with the attendant restrictions on travel and conferences, created too much uncertainty to properly stage the event. We will miss the dialogue with our acquisition colleagues and the opportunity for all our researchers to present their work. However, we intend to simulate the symposium as best we can, and these *Proceedings* present an opportunity for the papers to be published just as if they had been delivered. In any case, we will have a rich store of papers to draw from for next year’s event scheduled for May 14–15, 2014!

Despite these temporary setbacks, our Acquisition Research Program (ARP) here at the Naval Postgraduate School (NPS) continues at a normal pace. Since the ARP’s founding in 2003, over 1,200 original research reports have been added to the acquisition body of knowledge. We continue to add to that library, located online at www.acquisitionresearch.net, at a rate of roughly 140 reports per year. This activity has engaged researchers at over 70 universities and other institutions, greatly enhancing the diversity of thought brought to bear on the business activities of the DoD.

We generate this level of activity in three ways. First, we solicit research topics from academia and other institutions through an annual Broad Agency Announcement, sponsored by the USD(AT&L). Second, we issue an annual internal call for proposals to seek NPS faculty research supporting the interests of our program sponsors. Finally, we serve as a “broker” to market specific research topics identified by our sponsors to NPS graduate students. This three-pronged approach provides for a rich and broad diversity of scholarly rigor mixed with a good blend of practitioner experience in the field of acquisition. We are grateful to those of you who have contributed to our research program in the past and encourage your future participation.

Unfortunately, what will be missing this year is the active participation and networking that has been the hallmark of previous symposia. By purposely limiting attendance to 350 people, we encourage just that. This forum remains unique in its effort to bring scholars and practitioners together around acquisition research that is both relevant in application and rigorous in method. It provides the opportunity to interact with many top DoD acquisition officials and acquisition researchers. We encourage dialogue both in the formal panel sessions and in the many opportunities we make available at meals, breaks, and the day-ending socials. Many of our researchers use these occasions to establish new teaming arrangements for future research work. Despite the fact that we will not be gathered together to reap the above-listed benefits, the ARP will endeavor to stimulate this dialogue through various means throughout the year as we interact with our researchers and DoD officials.

Affordability remains a major focus in the DoD acquisition world and will no doubt get even more attention as the sequestration outcomes unfold. It is a central tenet of the DoD’s Better Buying Power initiatives, which continue to evolve as the DoD finds which of them work and which do not. This suggests that research with a focus on affordability will be of great interest to the DoD leadership in the year to come. Whether you’re a practitioner or scholar, we invite you to participate in that research.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the ARP:

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Naval Ship Maintenance: An Analysis of the Dutch Shipbuilding Industry Using the Knowledge Value Added, Systems Dynamics, and Integrated Risk Management Methodologies

David N. Ford, Thomas J. Housel, and Johnathan C. Mun
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Time as an Independent Variable: A Tool to Drive Cost Out of and Efficiency Into Major Acquisition Programs

J. David Patterson
National Defense Business Institute, University of Tennessee

The Impact of Globalization on the U.S. Defense Industry

Jacques S. Gansler and William Lucyshyn
University of Maryland

Bottleneck Analysis on the DoD Pre-Milestone B Acquisition Processes

Danielle Worger and Teresa Wu, *Arizona State University*
Eugene Rex Jalao, *Arizona State University and University of the Philippines*
Christopher Auger, Lars Baldus, Brian Yoshimoto, J. Robert Wirthlin, and John Colombi, *The Air Force Institute of Technology*

Software Acquisition Patterns of Failure and How to Recognize Them

Lisa Brownsword, Cecilia Albert, Patrick Place, and David Carney
Carnegie Mellon University

Fewer Mistakes on the First Day: Architectural Strategies and Their Impacts on Acquisition Outcomes

Linda McCabe and Anthony Wicht
Massachusetts Institute of Technology

The Joint Program Dilemma: Analyzing the Pervasive Role That Social Dilemmas Play in Undermining Acquisition Success

Andrew P. Moore, William E. Novak, Julie B. Cohen, Jay D. Marchetti, and Matthew L. Collins
Software Engineering Institute, Carnegie Mellon University

Acquisition Risks in a World of Joint Capabilities: A Study of Interdependency Complexity

Mary Maureen Brown
University of North Carolina Charlotte

Leveraging Structural Characteristics of Interdependent Networks to Model Non-Linear Cascading Risks

Anita Raja, Mohammad Rashedul Hasan, and Shalini Rajanna
University of North Carolina at Charlotte
Ansaf Salleb-Aoussi, *Columbia University, Center for Computational Learning Systems*

Lexical Link Analysis Application: Improving Web Service to Acquisition Visibility Portal

Ying Zhao, Shelley Gallup, and Douglas MacKinnon
Naval Postgraduate School

Capturing Creative Program Management Best Practices

Brandon Keller and J. Robert Wirthlin
Air Force Institute of Technology

The RITE Approach to Agile Acquisition

Timothy Boyce, Iva Sherman, and Nicholas Roussel
Space and Naval Warfare Systems Center Pacific

Challenge-Based Acquisition: Stimulating Innovative Solutions Faster and Cheaper by Asking the Right Questions

Richard Weatherly, Virginia Wydler, Matthew D. Way, Scott Anderson, and Michael Arendt
MITRE Corporation

Defense Acquisition and the Case of the Joint Capabilities Technology Demonstration Office: Ad Hoc Problem Solving as a Mechanism for Adaptive Change

Kathryn Aten and John T. Dillard
Naval Postgraduate School

A Comparative Assessment of the Navy's Future Naval Capabilities (FNC) Process and Joint Staff Capability Gap Assessment Process as Related to Pacific Command's (PACOM) Integrated Priority List Submission

Jaime Frittman, Sibel McGee, and John Yuhas, *Analytic Services, Inc.*
Ansaf Salleb-Aoussi, *Columbia University*

Enabling Design for Affordability: An Epoch-Era Analysis Approach

Michael A. Schaffner, Marcus Wu Shihong, Adam M. Ross, and Donna H. Rhodes
Massachusetts Institute of Technology

Measuring Dynamic Knowledge and Performance at the Tactical Edges of Organizations: Assessing Acquisition Workforce Quality

Mark E. Nissen
Naval Postgraduate School

Outcome-Focused Market Intelligence: Extracting Better Value and Effectiveness From Strategic Sourcing

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The Joint Program Dilemma: Analyzing the Pervasive Role That Social Dilemmas Play in Undermining Acquisition Success[1]

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Abstract

In the face of both declining budgets and growing interoperability requirements, the military increasingly wants to consolidate multiple needs into single systems to be developed jointly. Unfortunately, the track record for joint system acquisition programs is mixed, and programs often follow a familiar downward spiral:

> The stakeholder programs that depend on a joint system may be skeptical, fearing the needed capability will neither meet their needs, nor be delivered as promised. Stakeholders pressure the Joint Program Office (JPO) to accommodate individual requirements, and the JPO may reluctantly agree, driving up cost, schedule, complexity, and risk—thus realizing the stakeholders' worst fears. These performance issues encourage stakeholders to leave the joint program, potentially rendering it both operationally unattractive and financially infeasible.

This exemplifies a classic social dilemma called the "Tragedy of the Commons." Much work has been done on mitigating social dilemmas, but a solution's success depends on its context. This paper describes the modeling of organizational decision-making in a joint acquisition program using system dynamics. This permits future work to analyze the effectiveness of different social dilemma mitigations within the context of joint programs by using system dynamics.

Introduction

The failure of acquisition programs to deliver high-quality systems within cost and schedule constraints (GAO, 2005)—especially those developing software-reliant systems—is all too common in modern government acquisition. These recurring failures have a direct adverse impact on the ability of the Department of Defense (DoD) to be able to support the warfighter with the systems they need. Delayed systems withhold needed capability, and wasted resources drain budgets that could be used to develop other systems.

The Software Engineering Institute (SEI) has a unique insight into these failures from regularly conducting Independent Technical Assessments (ITAs) on specific programs to determine why they are experiencing difficulties. These investigations have provided visibility into the processes and forces at work within these programs and have produced an understanding of the most common ways that programs come to face serious challenges. Acquisition programs do not fail solely for technical reasons. Organizational, management, and cultural issues are an additional set of significant reasons why acquisition programs may substantially exceed budget, overrun schedule, deliver inadequate quality, and ultimately even fail (Frangos, 1998; Madachy, 2008).

This paper describes research that is being conducted to better understand the joint acquisition program dilemma and to investigate approaches to mitigate associated problems. The general approach is to use a causal loop diagram (CLD) as a means to capture a current understanding of the problem based on past experience in both consulting on joint programs and in conducting ITAs. The CLD embodies an evolving theory of the joint acquisition dilemma that is updated and refined through a series of workshops held with joint program domain experts and decision-makers. The evolving theory is further explored by developing the CLD into a fully executable system dynamics model. Data collected during workshops help to guide, correct, and validate important aspects of the model. When the model adequately captures the joint program dilemma, it can be used to investigate mitigations to the problem through additional modeling of different mitigation approaches. Ultimately, the most promising mitigations can be evaluated in the workshop context and potentially in pilot tests during the execution of actual joint acquisitions.

The subsequent portions of this paper describe the progress that has been made in conducting this research. The section Social Dilemmas and Joint Programs describes the typical flow of joint acquisition program events. The section System Dynamics Background provides an introduction to the system dynamics modeling approach. The section Workshop with Domain Experts describes the workshops that have been held thus far, and the primary insights gained. The section The Joint Program Simulation Model describes the current state of a system dynamics simulation model refined based on feedback provided during these workshops. Key behaviors exhibited by the model support the hypothesis that joint programs suffer from the "Tragedy of the Commons" social dilemma and that joint program participants may get caught in a trap that can lead to the demise of the program. The section Mitigations for the Joint Program Dilemma describes the space of potential mitigations and solutions to the problems illustrated. Finally, the paper concludes with a discussion of the implications of this work and some future opportunities.

Joint Programs

The category of programs known as "joint" programs constitute a special case within DoD acquisition. Such programs intend to provide a system, subsystem, or capability that will fulfill needs of, and be funded or managed by, more than one DoD service or component. Joint programs are appealing because they offer at least two significant potential benefits: (1) reducing costs by developing one system as opposed to several differing ones and (2) improving interoperability by providing a single system or capability that can be used for multiple purposes in multiple contexts. Joint programs are recognized as being difficult to manage because they have multiple stakeholder programs intending to use the joint capability (often with differing needs), they may be larger in size than other programs, they may be more complex organizationally, and they may be geographically dispersed—all causing increased levels of coordination, communication, and negotiation overhead. At the same time, joint programs are becoming increasingly important to the military as the need for interoperability grows and as there is greater pressure on the overall defense budget to reduce costs.

Although the focus of most acquisition programs is on the complex system being developed, it may be overlooked that acquisition programs themselves, especially joint programs, are complex, dynamic systems—and as such can display unpredictable and even seemingly chaotic behavior. This results from the presence of *feedback* between the autonomous actors populating different groups within the acquisition organization. Feedback in the system produces non-linear behavior, where changes in the system's outputs may no longer be proportional to changes to the inputs. The complexity of this feedback, inherent in any system involving interacting human beings, coupled with time delays between inputs and outputs that obscure the relationships between cause and effect, can produce unexpected behavior in even simple systems. Such systems must be analyzed as a whole in order to understand their behavior, because the problematic behaviors often emerge directly as a result of these interactions—and vanish when the system is decomposed into its component pieces for study.

Misaligned Incentives in Acquisition

It has been concluded in studies (Kadish, 2006; Pennock, 2008) that the incentives at work in acquisition policy and governance are often misaligned. These misalignments can cause a disconnect between the desired outcome and the most promising ways of achieving that outcome. The result of misaligned incentives can be shortsighted acquisition decision-making, potentially putting short-term interests ahead of longer term interests, or individual and program interests ahead of PEO and service interests, thus turning planned cooperation into opposition.

Many of the misaligned incentives seen in acquisition belong to a category of problems known as social dilemmas. Social dilemmas are ubiquitous across human organizations. They describe situations in which the incentives align to promote a solution by the actors involved that may be locally optimal but will be suboptimal at a more global level.

One common type of social dilemma is called a “social trap” (Cross & Guyer, 1980; Kollock, 1998). In a group context, a social trap means that an individual desires a benefit to himself that will cost everyone else—but if all in the group succumb to the same temptation, then everyone is worse off. A social trap is often referred to colloquially as a “Tragedy of the Commons”[2] (Hardin, 1968). What is noteworthy about this dilemma is that there is no intent to destroy the common resource—it’s the combined actions of all acting in their own self-interest that lead to the tragic result.

Social dilemmas come in many different forms, with many different properties, which helps to make them both difficult to recognize and difficult to fix. The next section outlines social dilemmas in the context of a joint program.

Social Dilemmas and Joint Programs

Joint programs are noted for the unique challenges that they face organizationally (Lindsay, 2006), due in part to the tension between the individual programs and services needing to look out for their own interests and the Goldwater-Nichols Department of Defense Reorganization Act of 1986 that stresses the importance of all service branches working together both effectively and efficiently. Because of this seeming paradox, there is a fundamental social dilemma at the heart of every joint program that can be seen in the following narrative, which summarizes the experiences of a number of joint and joint-style programs that the SEI has worked with:

> A joint program has six stakeholder programs all planning to integrate the joint infrastructure software that is being developed to meet a common baseline set of requirements. However, each stakeholder program then also requests that one or more significant new requirements be added to satisfy some custom needs of that specific stakeholder program. Although reluctant, the joint program manager agrees to the new requirements out of fear of losing stakeholder programs, who might leave the joint program to build their own custom software. As development proceeds, the additional requirements and their resulting design changes and incremental development significantly increase the total cost, schedule, complexity, and risk of the joint development effort. As the schedule begins to slip, one stakeholder program realizes that the joint program has put the stakeholder in danger of missing its own schedule, and so it leaves the joint program to develop its own software.

[2] The original story of the “Tragedy of the Commons” from the 19th century envisions a group of herders sharing an area of grazing land called a commons. If one herder decides to graze an extra animal, then that herder receives more benefit from the commons than the others, and at no additional cost to himself. However, if all of the herders follow suit and add more animals according to the same reasoning, they eventually reach the point where the grass is eaten faster than it can grow, the cattle begin to starve, and ultimately all of the herders lose their livelihood.

> Although one stakeholder program has left the joint program, the incremental cost of the more complex architecture that was designed to support the stakeholder's desired capability cannot be recouped. The schedule delays from the increased complexity and risk impact the remaining stakeholder programs as well, and soon another stakeholder program chooses to leave the joint program. Exacerbated by the effort spent in re-planning the joint effort each time a stakeholder program leaves, costs continue to escalate, and the development schedule lengthens. The remaining stakeholder programs begin to reconsider their participation in the joint program, and ultimately participation unravels and collapses.

With this narrative in mind, a joint program can be viewed as a "Tragedy of the Commons" in which the commons is the development resource of the joint program office and the contractor. The entire program and the stakeholder programs are collectively worse off if the stakeholder programs choose to exploit the development resource for their individual gain by insisting on having custom requirements developed.

It is important to note that a "Tragedy of the Commons" situation does not always occur in a joint program. It may be the case that strong leadership from the joint program manager, or a highly cooperative culture within the program, will prevent it from happening. However, given the fact that the incentives align to favor unilateral action by the stakeholder programs and their services, unless specific preventative steps are taken, preventing this social trap is more likely to be the exception rather than the rule.

The next section provides context for the creation of a system dynamics model of this behavior.

System Dynamics Background

The system dynamics method helps analysts model and analyze critical behavior as it evolves over time within complex socio-technical domains. A key tenet of this method is that the dynamic complexity of critical behavior can be captured by the underlying feedback structure of that behavior. The boundaries of a system dynamics model are drawn so that all of the enterprise elements necessary to generate and understand problematic behavior are contained within them. The method has a long history, as described in Sterman (2000) and Meadows (2008).

System dynamics and the related area of systems thinking encourage the inclusion of "soft" factors in the model such as policy, procedural, administrative, and cultural aspects. The exclusion of soft factors in other modeling techniques effectively treats their influence as negligible, which is often an inappropriate assumption. This holistic modeling perspective helps identify mitigations to problematic behaviors that are often overlooked by other approaches.

Figure 1 summarizes the notation used by system dynamics modeling. The primary elements are variables of interest, stocks (which represent collection points of resources), and flows (which represent the transition of resources between stocks). Signed arrows represent causal relationships, where the sign indicates how the variable at the arrow's source influences the variable at the arrow's target. A positive (S) influence indicates that the values of the variables move in the same direction, whereas a negative (O) influence indicates that they move in opposite directions. A connected group of variables, stocks, and flows can create a path that is referred to as a *feedback loop*. There are two types of feedback loops: balancing and reinforcing. The type of feedback loop is determined by counting the number of negative influences along the path of the loop. An odd number of negative influences indicates a balancing loop; an even (or zero) number of negative influences indicates a reinforcing loop.

Significant feedback loops identified within the model described here are indicated by a loop symbol and a loop name in italics. Balancing loops—indicated with the label *B* followed by an identifying number in the loop symbol—describe aspects of the system that oppose change, seeking to drive variables to some equilibrium goal state. Balancing loops often represent actions that an organization takes to manage, or mitigate a problem. Reinforcing loops—indicated with a label R followed by a number in the loop symbol—describe system aspects that tend to drive variable values consistently either upward or downward. Reinforcing loops often represent the escalation of problems but may include problem mitigation behaviors.

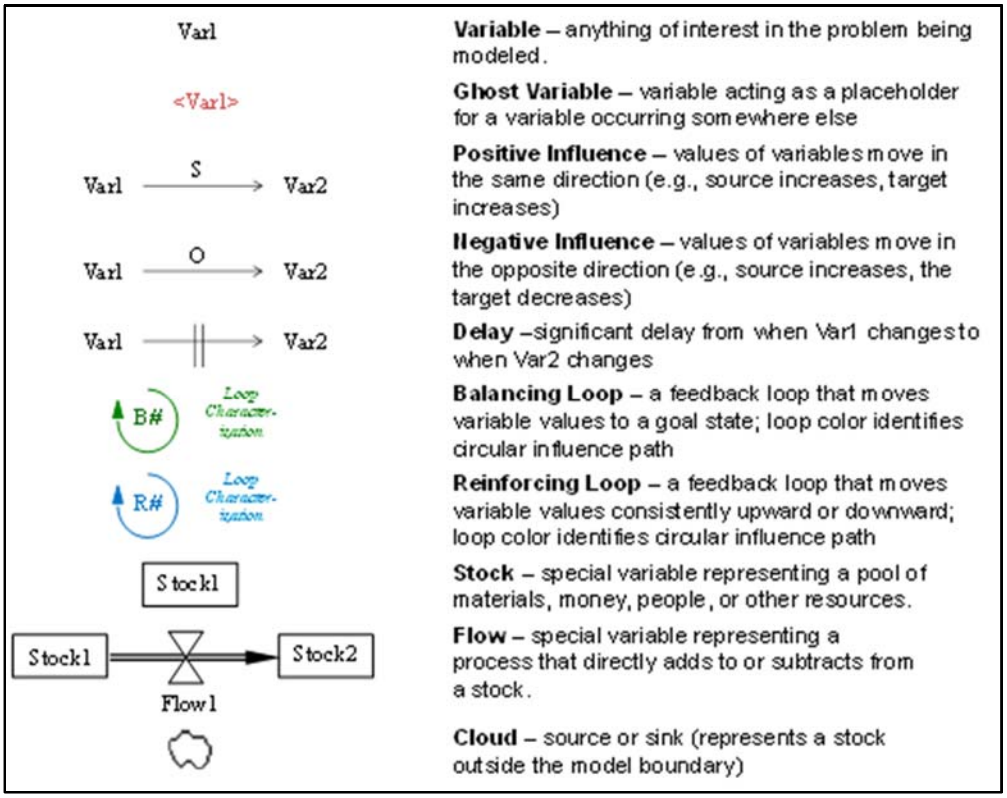

Figure 1. System Dynamics Notation

The next section discusses how the system dynamics modeling process was used to elicit a detailed understanding of joint program behavior from subject matter experts.

Workshop With Domain Experts

A series of *problem elaboration workshops*[3] is being used as the primary method for gaining feedback from acquisition subject matter experts on the current system dynamics model, and for eliciting suggestions for additional potential improvements. To date, a shortened pilot version of the problem elaboration workshop has been conducted with

[3] These workshops are covered by the Carnegie Mellon University (CMU) human subject research policy, and protocol HS12-237 for conducting these workshops has been approved by the CMU Institutional Review Board (IRB). Nothing discussed at the workshops is tied to a specific individual or organization.

internal SEI acquisition experts as well as a full two-day workshop with program office and contractor personnel from a single joint program.

The problem elaboration workshops are intended to consist of personnel drawn from a single joint program. Ideally each workshop will include a mix of program management and technical personnel as well as personnel from both the acquirer and developer side. The workshops last approximately two days in order to cover a substantial portion of the relevant material. The top-level causal loop diagram of the dynamic is reviewed as a high-level abstraction of the model because reviewing the entire system dynamics model is not feasible for the acquisition subject matter experts.

There are two primary goals for each problem elaboration workshop: (1) discuss the current top-level loops in the model causal loop diagram and have the participants rate the importance and accuracy of each loop using a Likert scale and (2) gain insight from the participants on any loops/interactions that may have been overlooked. The initial workshop focused on a joint program designed to provide a joint communication capability needed by several services that was to be deployed on a number of different platforms to allow for effective communication between platforms belonging to multiple services. The participants included personnel who had worked at the government program office and personnel from the prime contractor. The workshops were effective in achieving their goals, and some of the results are summarized as follows.

Goal 1: Rating the top-level loops. After presentation and discussion of all of the top-level loops in the CLD of the large model (see Table 1 in Appendix A for high-level descriptions of those loops and Figure 11 in Appendix B for a graphical depiction), ratings were obtained from all participants. Nine of the 12 loops in the CLD (75%) were rated above moderately important. In seven (i.e., 58%) of the loops, the average accuracy score was rated above moderately accurate. Of these seven loops rated above moderately accurate, four of these loops (33% of the original 12) were rated above very accurate. For all 12 loops, at least one of the four participants rated themselves as extremely experienced in this area, and all loops had at least two participants who rated themselves as very or extremely experienced. Based on the feedback from the participants, one section of the CLD that scored lower in importance was modified in order to change how stakeholder programs may influence others to defect, or leave the joint program.

Goal 2: Overlooked loops/interactions. The workshop participants discussed nine additional interactions that they thought had been important on their joint program. The top area they thought should be added addressed launching the program properly. The model was modified to address this area, and additional ways of implementing this concept are being explored. A second area that was identified as needing to be addressed is the level of capability of the government staff, and this has been added to the model as well.

Feedback from actual program personnel is critical to ensuring that the model includes the most important top-level interactions. It is also critical to tuning the model parameters to best simulate the performance of joint programs. Additional problem elaboration workshops are planned for the near future to continue to refine the model.

The Joint Program Simulation Model

As described previously, the problem elaboration workshop attendees were presented with a CLD that already described many aspects of joint program behavior. The feedback from these domain experts made it possible to assess the most important aspects of the joint program problem, many of which were included in the original CLD and some of which were not. This information was used to develop a simpler and more focused CLD that better represents the inherent social dilemma and other central aspects of the joint program dilemma as seen by the workshop participants. Appendix B contains this refined CLD.[4] As additional workshops are conducted, other aspects may be included or excluded from the CLD based on the findings of those workshops.

The only loops retained in this simpler model are the stakeholder custom requirements acceptance (B3), pressure-induced rework (R3), and pressure-induced attrition (R4), as described in Appendices A and B. The first two of these were the top two rated feedback loops at the workshop. The third, which is closely related to the second, occurs in most joint programs and causes significant turmoil and lost productivity. Also included is one of the two highest rated extensions proposed to the original model: The inclusion of Joint Program Office (JPO) efforts to keep the joint program sold to stakeholders was deemed a key contributing factor to endemic problems and inefficiencies. The top-rated extension that was suggested at the workshop, the distinction between acquiring capabilities as opposed to acquiring systems, will be addressed explicitly in future versions of the model.

The system dynamics method provides a way of implementing a CLD, so as to further explore the implications of the causal structure as it is elaborated in more detail. These implications are assessed through simulation (execution) of the model. In addition to the confidence gained in the CLD during the workshops, simulation can result in additional confidence that the causal structure can indeed produce the behavior implied by the qualitative CLD. Once the model has been shown to exhibit the expected behavior, workshop interactions can help ensure that it does so for the correct reasons. This level of validation then allows the analyst to use the model to test alternate solutions to the problem using the system dynamics simulation capability.

The simulation and analysis of the joint program model is still ongoing, and it is the initial results of that effort that are presented here. The feedback that was received in the initial problem elaboration workshop made it possible to simplify and focus the original simulation model that had been developed. The three primary segments of the current simulation model are described in order: the Stakeholder Program Segment, the Joint Program Office (JPO) Segment, and the Developer Segment. Each of the stakeholder programs, the JPO, and the developer have reasons to be at least comparatively satisfied based on the progression of events thus far, early on in the joint program acquisition. However, as will be seen in the subsequent section, Systemic Effects, their relative satisfaction will be spoiled due to the diminishing returns associated with joint program expenditures.

- The current model makes the following assumptions about the joint acquisition program:
- The timeline of the simulation is 120 months—10 years—but the conclusion of the project may be significantly short of that, and vary depending on the input parameters. Milestone B occurs 12 months into the simulation, and that is when the development contract is awarded.
- The joint program has three stakeholder programs that negotiate with the JPO for their own custom requirements separate from a set of baseline requirements. The stakeholder programs are referred to abstractly as S1, S2, and S3.

[4] Note that CLDs and system dynamics models share a similar notation. The primary difference is that CLDs do not include stocks or flows. They are strictly qualitative and so are not executable.

- Funding for the joint program is spent strictly on development activities. JPO staff can rotate out and be hired in, but the staff levels stay at generally the same level and do not consume funding (e.g., they are on overhead, as far as the model is concerned).
- Developer staff are separated into new staff versus experienced staff, each with their own levels of productivity (i.e., computer software configuration items (CSCIs)[5] developed/tested per month) and monthly costs. Experienced staff may have their time partially consumed by training new staff.

These assumptions may be relaxed in future revisions to the model to allow a broader range of behaviors to be tested.

It should be noted that although the model described as follows has been refined both by the problem elaboration workshop sessions and through the acquisition experience of the modeling team itself, this model has not yet been validated with historical joint program data to help quantify the relationships between the model variables. This validation will be conducted, but at this point, the model should be viewed as providing only tentative support for the causal hypothesis.

Stakeholder Program Segment

A primary concern of the stakeholder programs is getting their (custom) requirements implemented by the joint program so that they have the most usable system possible when the joint program completes development. There is a fair amount of negotiation going on during these times between the joint program office and the stakeholder programs, and the initial model is based on the foundations of negotiation and cooperation theory. Other work in developing system dynamics models has leveraged some of this theory in the past. This model is based explicitly on models developed by Darling and Richardson (1990).

As illustrated in Figure 2, stakeholder program decision-making is based on the following:

- *Stakeholder program gain* (the inner loop in the figure). The extent to which the stakeholder program's custom requirements are implemented in the joint system. In terms outlined by Darling, this gain limits the stakeholder program's problem potential. An effect function[6] is used to capture the framing effects of Darling's model, which is used to determine whether the extent of the stakeholder program's gain is viewed positively or negatively.
- *Stakeholder program's relative gain (the outer loop in the figure).* The stakeholder program's satisfaction is also dependent on how much they perceive others are gaining relative to their own gain. If they think others are getting proportionally more, then they will be less satisfied even if they are still getting their own needs met adequately. This is a refinement of Darling's model, which was based on a weighted sum of the gain for self and the perceived gain of other stakeholder programs.
    - A more recent perception of gains weighs more in stakeholder program decision-making than older perceptions. This relates to the moving average used in the Darling model, which models how past outcomes influence present expectations.

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[5] A CSCI is a collection of software that supports a specific function for the end user.

[6] An effect function is a device used in system dynamics modeling that explicitly describes the mathematical relationship between two specific model variables over time.

- The possibility that a stakeholder program may have only a limited understanding of other stakeholder programs' gains (Darling's "Fixed Pie Bias") is handled with a weighted formula. To the extent that understanding is incomplete (i.e., knowledge of other's gain is less than 1), a stakeholder program assumes that their loss is the other stakeholder program's gain.

Initial discussion with joint program decision-makers suggests that concern for fairness, as described in Darling's model, is not a primary factor in stakeholder program decision-making, so it has been omitted from the simplified model presented here. It is, however, still a factor in the larger model being developed.

A stakeholder program's satisfaction influences both the extent of their buy-in to the joint program and their cooperation with the joint program goals. Both buy-in and cooperation with the joint program are needed to keep the program viable. When either is lagging, the JPO will tend to implement more of the stakeholder program's custom requirements to keep the stakeholder program engaged.

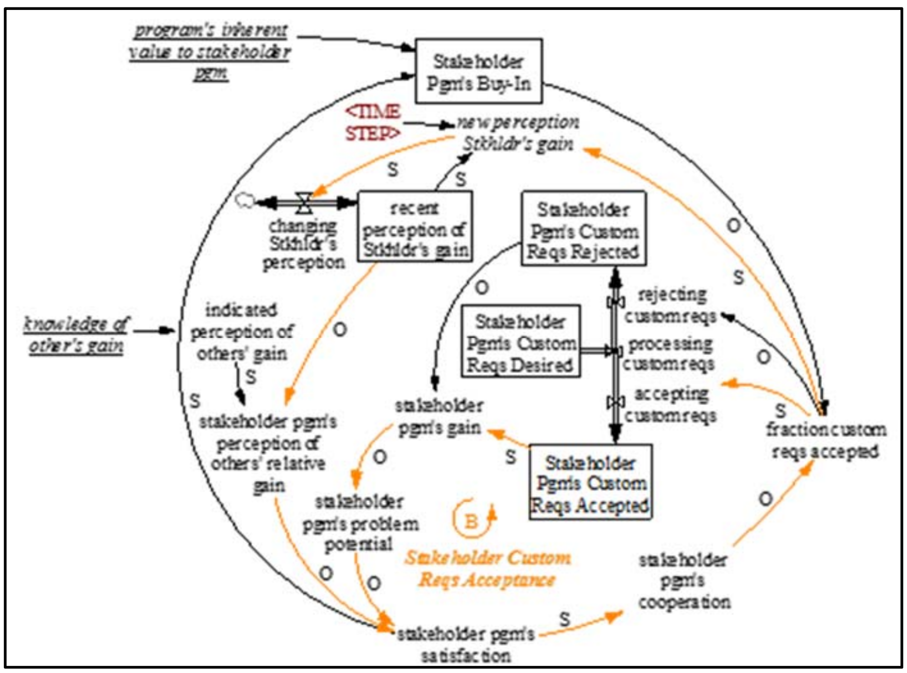

Figure 2. Stakeholder Programs Negotiate for Custom Requirements Beyond Baseline

This effect can result in an escalation of custom requirements, which of course must then be integrated with the original requirements. The model initial settings are set to an equilibrium. At Month 18, to test the behavior of the model, the demands of stakeholder S1 are stepped up to a level of 0.8 on a scale of 0 to 1. This perturbation from equilibrium shows in Figure 3 that increases in one stakeholder program's demands leads to increases in other stakeholder programs' demands. Although the levels do not rise to the same degree, the escalation of custom requirements that result are necessary from the joint program perspective in order to maintain stakeholder programs' buy-in and prevent stakeholders from defecting.

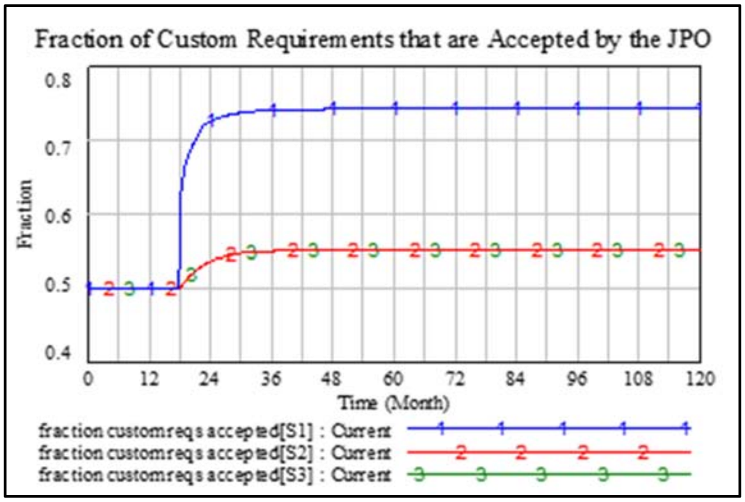

Figure 3. Increase in Custom Requirements Acceptance for S1 With Subsequent Rise for S2 and S3[7]

In the Darling model, this behavior reflects the "competitive drift" possible, where one negotiator is pitted directly against another and the interaction between negotiators becomes increasingly acrimonious. In the joint program case, the JPO may feel compelled to give in to stakeholder program demands across the board, directly supporting the creation and reinforcement of the underlying social dilemma. With greater support being given to their individual needs, the stakeholder programs remain relatively satisfied.

Joint Program Office (JPO) Segment

The benefit of keeping stakeholder programs "bought in" to the joint program is evident in Figure 4. More engaged program stakeholders promote DoD buy-in. Once the development starts, especially with the additional custom requirements accepted, plus-ups on funding and extensions to the schedule are usually necessary to implement the additional functionality.

---

[7] This and subsequent graphs were generated using the Vensim modeling tool. These are all behavior-over-time graphs, and as such, the x-axis for these graphs is specified in months (120 months—10 years—is the duration of this simulation). Each simulation run is specified as individual graphs distinguished with a number label (1 through 3 in Figure 3), as specified in the legend below the graph.

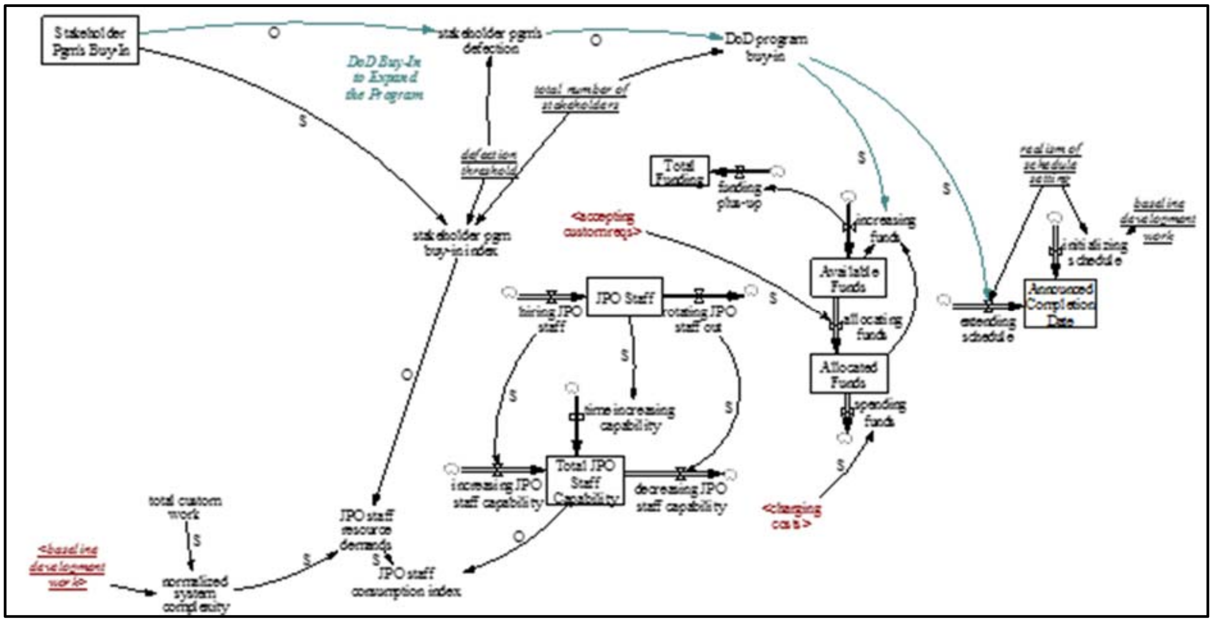

Figure 4. JPS Benefits From Increased Stakeholder Program Buy-In by Keeping the Program Alive

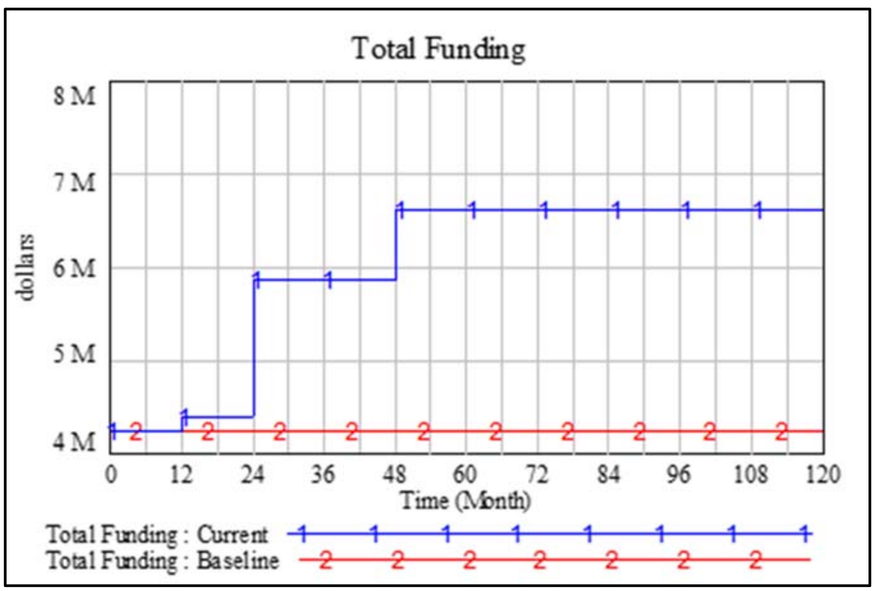

Figure 5. Additional Funding Increments to Implement Expanded Scope

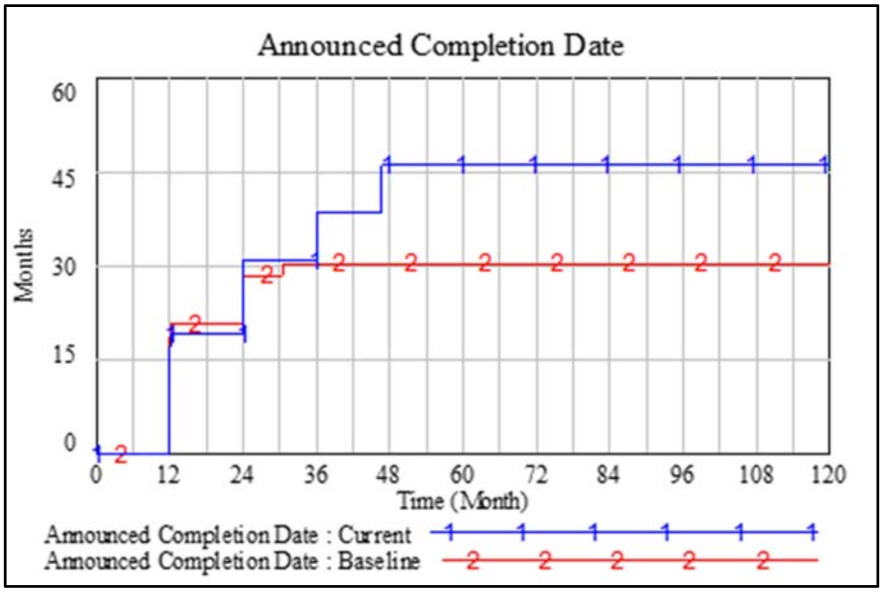

Figure 6. Additional Schedule Extensions to Implement Expanded Scope

Developer Segment

The additional development work generated due to the additional custom requirements from the stakeholder platforms is shown in the middle of Figure 7. This additional development work, along with the development work from the originally planned baseline, is added to the development work remaining. Both development and testing work is accomplished based on the productivity of the development staff, shown on the left side of the figure.

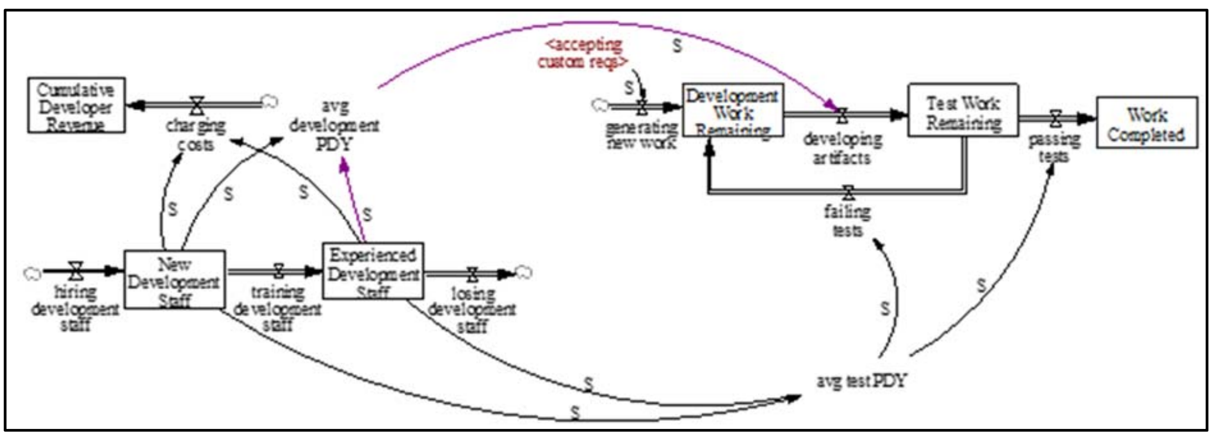

Figure 7. Development Staff Managed to Complete Development Work

Development staff is split between new hires and experienced staff, with some training period (possibly on-the-job) needed to transition from new to experienced. The development productivity levels of new and experienced staff differs, with experienced staff spending some of their time training the newer staff. All charges made by the staff for their time working on the project are reflected in the cumulative contractor (i.e., developer) revenue. As shown in Figure 8, the contractor's revenue rises well above the baseline levels, partially due to implementing the additional custom requirements demanded by the stakeholder programs. In this context, assuming that the contractual negotiations are providing additional revenue for the additional employees, the contractor is willing (if not even happy) to employ more staff for a longer period.

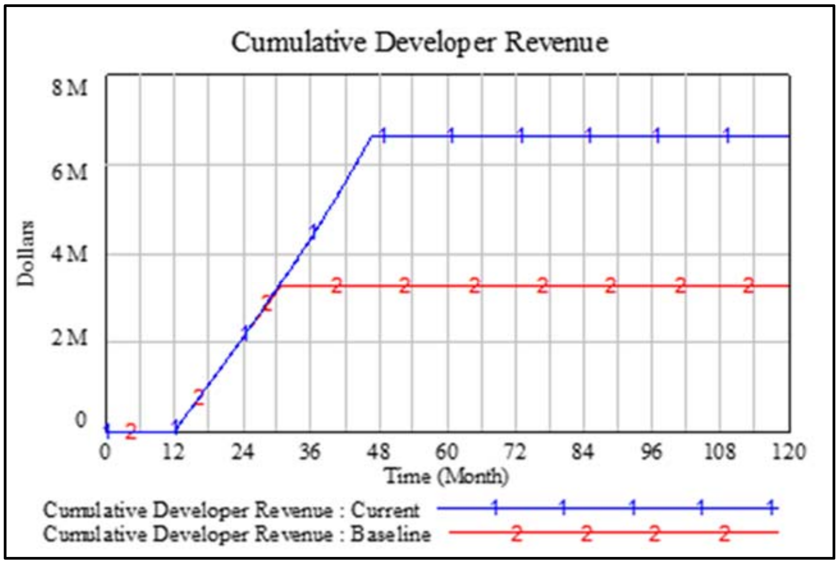

Figure 8. Developer Revenue Rises Well Above the Baseline Level[8]

Systemic Effects

Although the stakeholder programs, the JPO, and the developer accomplish important objectives in their own domains, these objectives act as a trap for joint program decision-makers that can potentially lead to the demise of the joint program. Figure 9 shows the diminishing returns related to the joint program investment to develop the extended joint system. As the number of custom requirements accepted for each stakeholder program increases along the x-axis, the average cost per CSCI increases by a factor of 5 to 10 over the average cost per CSCI in the baseline development. Another dimension, along the z-axis, shows that as the realism of schedule setting decreases from 1 to 0.1, the CSCI cost ratio declines even further. As a result of the simulation and analysis of this scenario, representations of complex decision surfaces such as shown in Figure 9 allow decision-makers to understand the interactions between multiple factors within a system, and to understand the range of possible outcomes based on various actions.

[8] Development is complete about Month 30 in the Baseline simulation run and about Month 47 in the Current run.

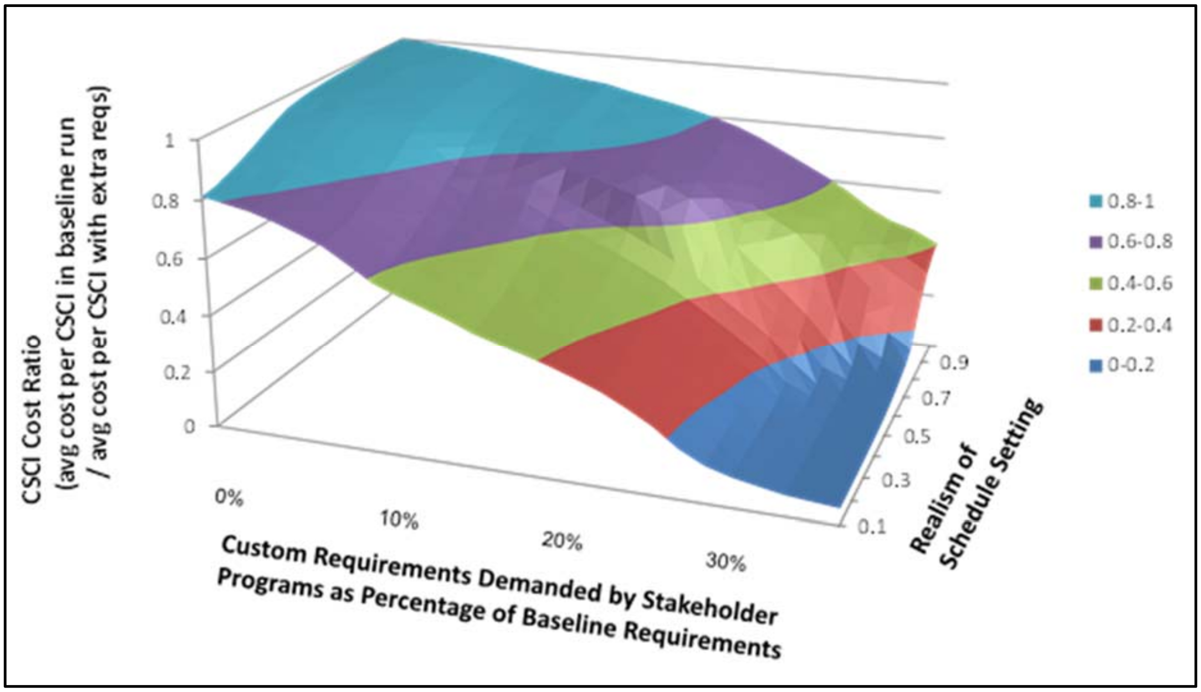

Figure 9. Systemic Result: Diminishing Returns in Development Effort Lead to Cost Increases for Program

The overview model, shown in Figure 10, integrates the stakeholder program segment, the JPO segment, and the developer segment described previously. The model also illustrates the primary influences causing the diminishing returns:

- *Complexity-Induced Rework* (in blue in the lower middle of the figure)—The system complexity that results from program stakeholder custom requirements decreases average development productivity and increases the rates of defect injection during development. The increased system complexity increases the complexity of developing individual CSCI for a variety of reasons, making development take longer and be more error prone.
- *JPO Staffing Effects on Program Execution* (in green in the lower middle of the figure)—The resource demands on the JPO staff, as described previously in the JPO segment, causes two primary problems for the developers. First, the JPO staff is not as responsive to developer demands for guidance, and for review and feedback on development artifacts. This reduces the average developer productivity. The second effect is that the JPO staff shortcuts the quality of their guidance and review process. This leads to lower quality in the development, and greater amounts of rework.
- *Pressure-Induced Rework* (the red reinforcing feedback loop)—The expansion of the joint system scope leads to the need for extensions to the schedule well beyond those planned for the original baseline system. Although the need for schedule extensions is widely recognized, they may come infrequently at unpredictable times, and only if decision-makers remain adequately bought in. The result is intense schedule pressure, which may be evident even early in the program if the initial schedule was unrealistic. Such schedule pressure can lead to bypassing some quality processes, and to the

generation of higher levels of rework. This acts in a reinforcing manner as schedule pressure escalates even further.

- *Pressure-Induced Attrition* (the purple reinforcing feedback loop)—Development staff may suffer the most from schedule pressure. When development staff are in high demand, attrition may grow. Despite new development staff being hired, the average and thus the overall productivity may fall, making it even harder to meet schedule demands. This reinforcing dynamic exacerbates the problem further.

This section described the hypotheses about why joint programs can get trapped into a development of diminishing returns. The four causes for these diminishing returns, described previously, provide a view of what can go wrong. Mitigation of this problem may involve developing a means to avoid falling into the trap in the first place or for reducing the negative consequences associated with falling in the trap. The next section describes some of the considerations regarding problem mitigation.

Mitigations for the Joint Program Dilemma

The rationale for identifying a possible inherent social dilemma at work within the structure of a joint program is to understand the mechanism by which these types of acquisition programs can encounter difficulties. Once the mechanism has been confirmed, there is a large set of mitigations and solution approaches that have been developed in different academic disciplines such as game theory, behavioral economics, social science, and social psychology, with each addressing differences in the specifics of the instance of the dilemma. Elinor Ostrom received the 2009 Nobel Prize in Economics for her study of innovative solutions that have evolved in different cultures to address differing instances of the "Tragedy of the Commons." However, these academic solutions are not well known to the software-intensive acquisition or software development communities and thus have not yet been studied in the context of acquisition programs, so their applicability is still unknown. The goal, however, remains the same—to deploy higher quality systems to the field in a more timely and cost-effective manner.

The research literature organizes the solutions to social dilemmas such as the "Tragedy of the Commons" into three classes:

- *Motivational*. Motivational solutions assume that participants are not exclusively self-interested and thus care about the consequences of their actions on other participants. Because of this, such concerns as values and group identity, as well as communication, can be effective.
- *Strategic*. Strategic solutions assume that participants are exclusively self-interested and so require that the participants influence how the other participants behave, thus producing a better outcome for themselves. Robert Axelrod (1984) provided three ingredients for such approaches: (1) long-term relationships among the participants (so that all expect shared dilemmas in their future), (2) that the participants can identify one another, and (3) that participants are aware of the past behavior of each other.
- *Structural*. Structural solutions require changing the rules of the situation so that the nature of the dilemma also changes. The most significant difficulties with applying structural solutions is that (1) they require a level of authority to implement, (2) they may bring about resistance from those who are affected, and (3) they require methods (with accompanying costs) to ensure compliance with the new rules.

The first two classes (i.e., motivational and strategic) do not require changing the fundamental structure of the situation, and as a result, they tend to be simpler to implement—although their effectiveness is less certain when compared to a structural solution.

To discuss one common approach to resolving a social trap,[9] the use of an *authority* to manage the commons is widely used in practice. However, this approach may have side effects, depending on how the leader was selected and from which organization, since the perceived objectivity and neutrality of the leader is essential to their acceptance by the participants.

Another widely used approach is *privatization*, which, like the use of authority, also has side effects. By removing the social aspect of the social dilemma, it eliminates the interdependence between people by converting shared ownership to private ownership. However, this would result in each of the stakeholder programs building their own custom system, which is antithetical to the originally intended outcome.

Another approach that could produce a better outcome might be altruistic punishment (Fehr & Gachter, 2002). In *altruistic punishment*, cooperating participants may penalize uncooperative participants through some mechanism (such as withholding a small funding increment) at a small cost to themselves. Participants seem willing to do this, despite the cost—and even if it will yield no direct material gain to them. Fehr and Gachter's research indicated that cooperation increases if altruistic punishment is possible and may break down if it is ruled out. In addition, imposing a cost on the administering party disincentivizes overuse, making it self-correcting.

Such a solution could help to avoid the requests for additional capabilities and prevent the downward spiral due to a lengthening schedule and increasing cost, complexity, and risk, thus incentivizing stakeholder programs to stay with the joint program, rather than defect. However, this particular solution to the social trap may or may not be feasible for use on a joint program.

Another way of addressing a social trap would be a strategic approach: making a series of small changes to the incentive and reward structure of the program, such as improving communications, making negative behaviors more visible to all participants, and similar modifications. Although no single such change would be likely to significantly mitigate the problem, it may be that the aggregate effect of many small changes to the program structure, when taken together, could have a substantial positive impact.

Other solutions to addressing social dilemmas exist, such as building trust, exclusion mechanisms, assurance contracts, and many others. The choice of the best solution will depend on the specific circumstances surrounding the specific joint program dilemma.

The defense acquisition system itself poses some significant challenges to successfully mitigating the types of problems that are inherent to joint programs and common infrastructure programs. When looking at the structural, strategic, and motivational classes of solutions to social dilemmas, it is apparent that motivational solutions, while attractive due to their generally lower level of effort to implement, may have little ability to effect change if the participants have substantial self-interest. The knowledge that "the complicated acquisition system generates staggering bargaining and coordination costs" such as "bureaucratic politics including inter-service rivalry, Joint service logrolling" (Lindsay, 2006) make a belief in the services having low levels of self-interest seem unlikely. Strategic solutions are more pragmatic but rely largely on the reputation of individuals and longer term

[9] Social traps were discussed in the section Misaligned Incentives in Acquisition.

relationships between negotiating parties, both of which are in short supply in a military where “the average tenure for program management in DoD is only 18 months” (McConnell, Sickler, & Yang, 2004). Structural solutions thus may appear to have the most promise of the three classes, although convincing all of the authorities required both to implement and enforce new rules on all parties in a joint program context may prove to be problematic.

The research with the system dynamics model of joint programs that is being developed involves the selection of some of the most promising mitigation and solution approaches, and modeling those approaches in the context of the joint program model. By assessing the ability of these solution approaches to mitigate the key adverse dynamics that are often present in joint programs, it will be possible to identify a set of the most promising approaches that could be applied in practice to try to avoid these issues in an actual joint acquisition program.

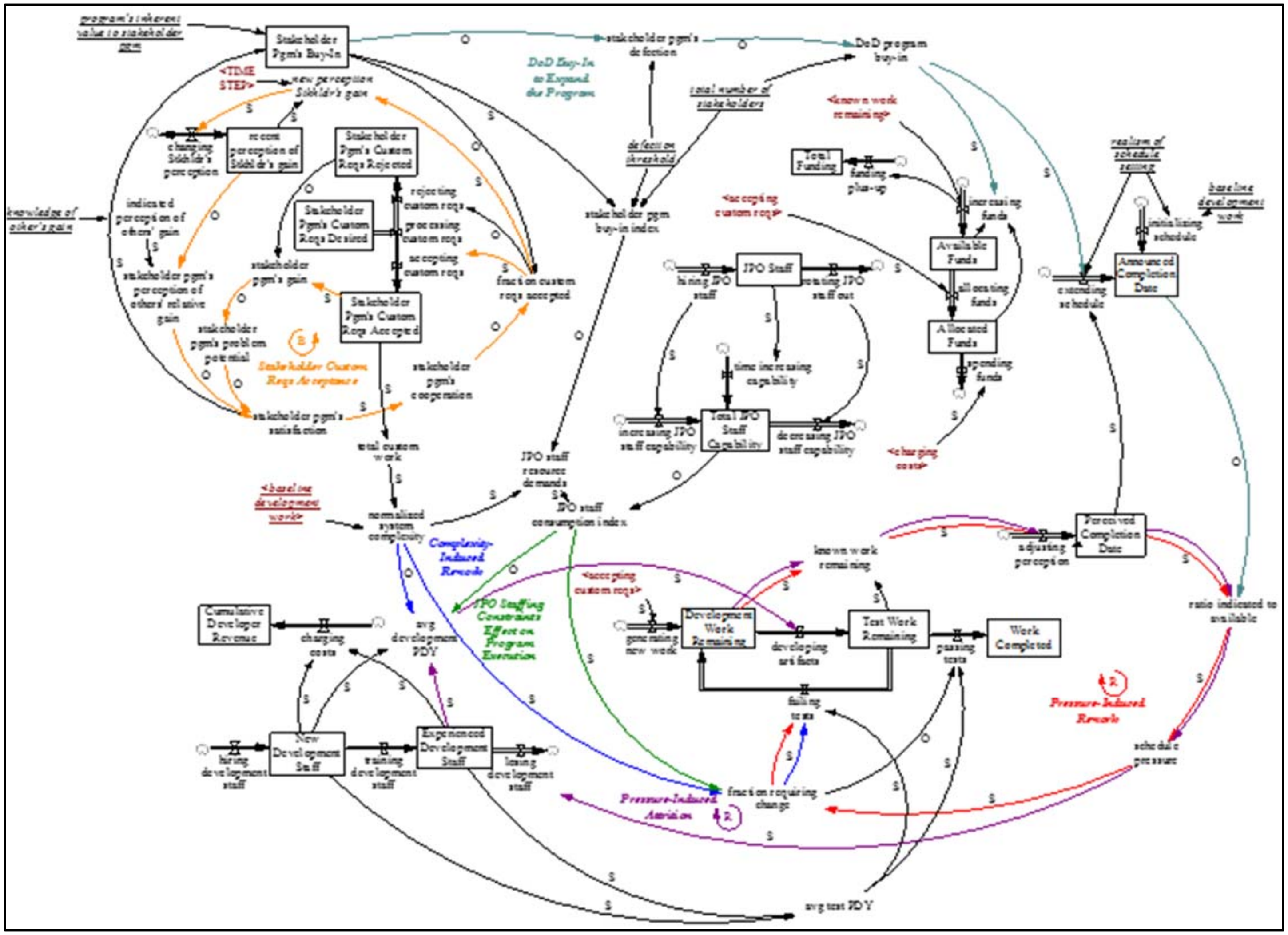

Figure 10. Simulation Model for Joint Acquisition Program Dynamic

Future Work

Some of the possible areas for future work will involve additional refinement and validation of the simulation model through review and feedback by joint acquisition domain experts, as well as calibration with historical program performance data. Once sufficient confidence in the model is gained through validation, it can be studied further to understand how the different key model variables are interrelated, and contribute to the causes of problematic behaviors. Complex surfaces, such as the one shown in Figure 9, can be created to give a sophisticated understanding to decision-makers as to how multiple variables interrelate and interact. The model can thus be used as a management decision aid to gain an understanding of what might occur in the future if current conditions continue unchanged and to explore hypothetical "what if" scenarios based on potential decisions and events. As the work proceeds, candidate motivational, strategic, and structural mitigations to the problematic dynamics of the joint program social dilemma will be developed and simulated to assess their effectiveness and viability, and to help develop potential new approaches and even policy recommendations to help improve the execution of these types of programs.

Although no model can accurately predict with consistent accuracy the future states of a complex dynamic system such as an acquisition program, Donella Meadows (1974) pointed out that "this level of knowledge is less satisfactory than a perfect, precise prediction would be, but it is still a significant advance over the level of understanding permitted by current mental models."

Conclusion

This paper describes the results of a preliminary investigation into the problems encountered by joint acquisition programs. Through interaction with joint acquisition experts, decision-makers, and stakeholders, a CLD now exists that represents a refined understanding of the problem. The CLD embodies a growing comprehension of what happens in joint acquisition programs and why the stakeholder programs, the JPO, and the developer can become trapped in behaviors that make rational sense to the participants at the time but can lead to diminishing returns and potentially failure for the program. It describes the inherent social dilemma that exists within joint programs—and provides the basis for a better understanding of the problem and for developing ways of mitigating it to minimize future joint program challenges.

References

Axelrod, R. (1984). *The evolution of cooperation.* New York, NY: Basic Books.

Cross, J. G., & Guyer, M. J. (1980). *Social traps*. Ann Arbor, MI: University of Michigan Press.

Darling, T. A., & Richardson, G. P. (1990). A behavioral simulation model of single and iterative negotiations. In *Proceedings of the 1990 International System Dynamics Conference* (pp. 228–241). Chestnut Hill, MA: System Dynamics Society.

Fehr, E., & Gachter, S. (2002, January). Altruistic punishment in humans. *Nature, 415*, 137–140.

Frangos, S. A. (1998). Motivated humans for reliable software products. *Microprocessors and Micro-Systems, 21*(10), 605–610.

GAO. (2005). *DoD acquisition outcomes: A case for change—Statement of Katherine V. Schiasi, managing director.* Washington, DC: Author.

Goldwater-Nichols Department of Defense Reorganization Act of 1986, Pub. L. No. 99-433 (1986, October 1).

Hardin, G. (1968, December). Tragedy of the commons. *Science, 162*, 1243–1248.

Kadish, R. (2006). *Defense acquisition performance assessment report: Assessment panel of the defense acquisition performance assesment project*. Fort Belvoir, VA: Defense Acquisition University.

Kollock, P. (1998, August). Social dilemmas: The anatomy of cooperation. *Annual Review of Sociology, 24*, 183–214.

Lindsay, J. R. (2006). *War upon the map: The politics of military user innovation*. Political Science. Cambridge, MA: Massachusetts Institute of Technology.

Madachy, R. J. (2008). *Software process dynamics*. Wiley-IEEE Press.

McConnell, J., Sickler, J., & Yang, T. (2004). *The problems behind the problems: Systems engineering and program management risk factors in acquisition programs*. Alexandria, VA: Institute for Defense Analyses.

Meadows, D. (1974). *The limits to growth* (2nd ed., revised). Signet.

Meadows, D. (2008). *Thinking in systems: A primer*. White River Junction, VT: Chelsea Green Publishing.

Pennock, M. J. (2008). *The economics of enterprise transformation: An analysis of the defense acquisition system.* Atlanta, GA: Georgia Institute of Technology.

Sterman, J. D. (2000). *Business dynamics: Systems thinking and modeling for a complex world.* McGraw-Hill.

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Appendix A: Feedback Loops Discussed in Workshop

Table 1. Loops of the Original CLD Discussed at the Problem Elaboration Workshop

Loop	Name	Description
R1	Stakeholder Bandwagon	Low stakeholder satisfaction can lead to a desire to defect, as well as attempts to influence other stakeholders to defect, causing a vicious cycle that can collapse the joint program.
B1	Membership Management	Lack of stakeholder support can lead to low service support, especially if the program's value to the service is low. This may require a greater "marketing" effort by the JPO to sustain stakeholder support.
B2	Program Support	Lowered service support can undermine DoD support, requiring still more JPO "marketing" effort to keep the stakeholders engaged.
R2	Stakeholder Confidence in JPO	Stakeholder support can grow as the progress of the grogram adheres to the schedule set forth. However, if the program falls behind schedule, stakeholders may become dissatisfied, start to lose confidence, and ultimately even defect.
B3	Stakeholder Custom Requirements Acceptance	Stakeholders are especially concerned with meeting their own custom requirements. To the extent those requirements are not addressed, the stakeholders may insist, and the JPO may eventually need to accept their requirements.
B3b	Stakeholder	As more of a stakeholder's custom requirements are accepted, fairness to others may

	Concern for Fairness	come into play. The stakeholder may become more cooperative, lowering his/her demands for more custom requirements.
B4	Honey Rather than Vinegar	The JPO may resist accepting custom requirements if the stakeholder becomes too demanding. The stakeholder may then reassess, becoming more cooperative if he thinks more of his custom requirements will be accepted.
R3	Pressure-Induced Rework	Accepting custom requirements leads to expanded program scope. Without schedule relief or additional staff, this puts additional pressure on workers, potentially causing them to bypass quality processes, thus resulting in more rework.
B5	De-scoping	To reduce schedule pressure and try to get development back on track, the JPO may eliminate requirements or defer them to a later development phase.
R4	Pressure-Induced Attrition	If sustained, excessive schedule pressure can disgruntle developers, leading to attrition, and making it even harder to meet schedule demands.
R5	Stakeholder Missing their Schedule	Delaying the schedule past the stakeholder's need date for the capability increases dissatisfaction, and can be a primary cause of defection.
R6	Stakeholder Escalating Costs	Expanding project scope can lead to greater shared costs to each stakeholder. This may increase discontent and lead to greater demands to meet custom stakeholder requirements, especially early on.

Appendix B: Simplified Causal Loop Diagram

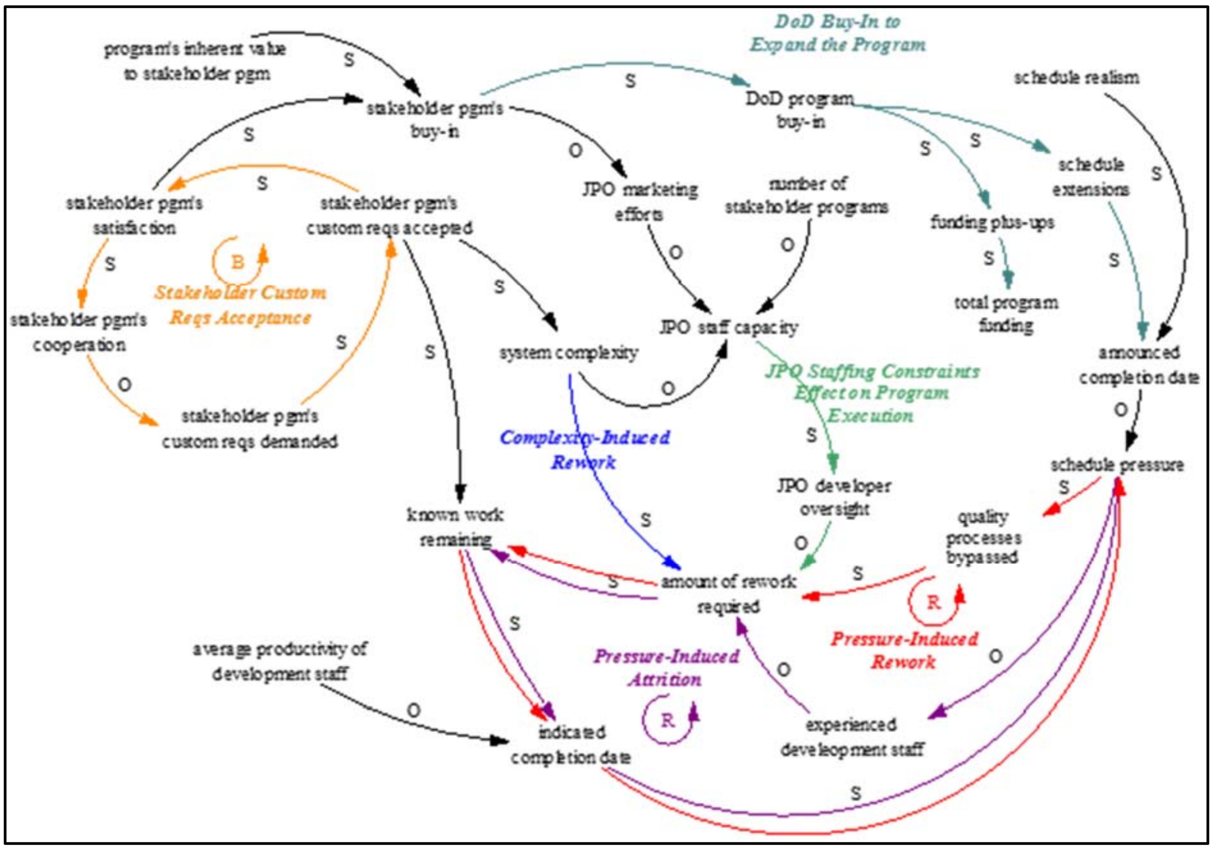

Figure 11. Causal Loop Diagram of the Joint Program

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