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Using Force-Field Analysis as Part of Systems Engineering Strategy to Achieve Goals

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Abstract. This paper provides an overview of Force-Field Analysis (FFA) and how to employ it within a defined systems engineering strategy framework to help achieve systems engineering goals. The systems engineering strategy framework has previously been introduced; it includes a high-level model and a set of classes and attributes to facilitate systems engineering strategic decision-making. However, no specific methods have been presented for how to use that framework to help achieve goals. FFA provides such a method, considering enablers and barriers related to achieving a goal. A strategist uses FFA to identify actions an organization can take to address the defined enablers and barriers. An example is provided to illustrate the use of FFA in the context of a systems engineering organization.

Introduction

The manner in which systems engineering is performed can be part of an organization's strategy and can lead to sustained competitive advantage for an organization [Smartt and Ferreira, 2011]. Strategy is defined as "the art of devising or employing plans toward a goal" [Merriam Webster, 2017]. Systems engineering strategy is defined as "any application of strategy applied to systems engineering" [Smartt and Ferreira, 2011]. Examples of systems engineering strategy include how to develop systems engineering capability within an organization, how to tailor systems engineering processes or reviews for a particular project, and how much of an engineering labor budget to allocate to systems engineering functions on a project.

The authors defined a systems engineering strategy framework [Smartt and Ferreira, 2011] and refined that framework through additional analysis and modeling [Smartt and Ferreira, 2012]. The framework includes a set of classes and attributes to consider when making strategic decisions related to systems engineering. The framework has been conceptualized as a state transition model and textual narratives have been published to offer examples of how to use the framework [Smartt and

Ferreira, 2011]. In addition, high-level use cases and actors of the systems engineering strategy framework have been defined [Smartt and Ferreira, 2012]. However, more systematic methods are needed for how to use the framework for systems engineering strategic decision making.

This paper suggests force-field analysis (FFA) as a method for planning how to attain a particular goal. FFA examines factors (called "forces") that are driving an organization or individual toward or away from achieving a particular goal, and provides a systematic approach for how to harness or overcome those forces. The concepts of goals and FFA are first explored. Guidance is offered for how to use FFA as part of systems engineering strategy, including how to use the classes and attributes from the systems engineering strategy framework as factors to consider when performing FFA. An example is then discussed related to the use of Model-Based Systems Engineering (MBSE) on a pilot project.

Goals

To define a strategy presupposes a desired outcome (a goal). Many leaders in organizations focus extensively on goals. The academic research on goal setting justifies this focus. In general, research has shown that setting challenging goals leads to higher performance than setting no goals or setting easy goals [Locke et al., 1981] unless goals surpass a particular level of difficulty [Erez and Zidon, 1994; Roose and Williams, 2018]. If a goal does surpass a particular level of difficulty, some research has found that teams tend to begin to reject the goal. There are exceptions involving groups comprised of people with high efficacy [Pilegge and Holtz, 1997].

There are multiple definitions for goals. One example is "the end toward which effort is directed" [Merriam Webster, 2017] and another is "what an individual is trying to accomplish; it is the object or aim of action" [Locke et al., 1981]. These definitions offer little insight as to how one formulates a goal in a productive way.

There are numerous publications and many consulting practices with a mission of driving effective goal setting. Doran [1981] first published that well-formulated goals met the following criteria: Specific, Measurable, Assignable, Realistic and Time-Related (SMART). More recently other authors have defined the letters in the SMART acronym in various ways (e.g., "Achievable" and "Agreed-Upon" for the A), and Wade [2009] provides a list of alternative meanings for each letter. The SMART goal framework has been used and referenced in management consulting circles [Day and Tosey, 2011]. While the SMART goal criteria are all desirable aspects of goals, they do not consider the potential undesirable impacts.

Casey et al. [2008] define the concept of Whole Goals. Whole Goals focus on an unambiguous and verifiable end state and offer restrictions, which are conditions that are not to be violated in the pursuit of the goal. These restrictions often seek to focus the goal and guard against unintended consequences of pursuing the goal. In this paper, goals are discussed as Whole Goals.

There are many methods for achieving goals and such methods fall into category of goal mechanisms in the larger goal theory related literature [Locke & Latham, 2002]. FFA is one among a number of methods for planning goal attainment. Others include SWOT analysis, analysis of strengths, weaknesses, opportunities, and threats [Learned et al., 1969], and nominal group technique [Delbeq et al., 1975]. This paper focuses on FFA because it is systematic, scalable, flexible (i.e., it can be applied to any Whole Goal), and it is frequently used by practitioners to develop strategies [Burnes and Cook, 2013].

Force Field Analysis

In the most general terms, FFA includes an examination of factors (viewed as forces) to achieve some goal, and facilitates identifying actions that would achieve the goal. FFA helps to both overcome forces that work against and leverage forces that work in favor of achieving some goal. FFA can be used to tackle personal goals such as getting your kid to earn better grades, attaining a healthier body weight, or saving more money for retirement. Also, management consultants commonly use FFA to help organizations understand what needs to be done to achieve their goals or to dislodge the organization from some undesirable state of equilibrium that is impeding progress. Such organizations often use FFA to overcome organizational challenges, such as diversifying the customer base, retaining employees and allowing an organization to be sustainable after key founding members have departed. The venues in which FFA has been applied and the problem sets it has targeted are diverse. For example, it has been successfully applied in healthcare [Wade, 2009; Wooten, 2000], total quality management [Hensey, 1993], project management [Nichols, 1989], adult education [Miller, 1967], and public policy [Lan and Lee, 1997]. So, part of the attraction of FFA for organizational planners is its scalability and its flexibility.

FFA emerged as part of Lewin's larger work on field theory or what he called "topological psychology" [Cartwright, 1952]. The formalisms in this topology laid the theoretical foundation for most of his work [Cartwright, 1952]. Lewin attempted to mathematically express the entire space of factors influencing a person [Lewin, 1943]. Lewin's work is highly influenced by gestalt psychology [Burnes and Cook, 2013] and strives to holistically examine the factors influencing decision-making. While research dwindled in this area after Lewin's efforts, there has been a resurgence in both scholarly research related to FFA and also increased application of FFA to help people solve real-world problems [Burnes and Cook, 2013].

Forces and Force Fields

To understand how to use force field analysis, one must understand the concepts of forces and force fields. In physics, force is viewed as being applied to an object and is conceptualized as a vector with both magnitude and direction with the vector of force equal to the change in the vector of momentum over time [PhysLink, 2017]. In physics, a force field is the sum of all forces acting on an object.

Some scholars of FFA [Cronshaw and McCulloch, 2008] believe that a careful read of the seminal work in FFA [Lewin, 1943] require an adherence to this physics-based conceptualization which, when applied to an organization's strategy formulation, focuses exclusively on forces external to the organization. Since then, many practitioners have broadened their perspective to include both forces external to an organization and forces internal to it. This paper adopts this more expansive view, considering both forces external and internal to the organization. In the context of FFA, a force is defined as "any influence acting in an organization such that the organization's state is changed by the presence of that factor" [Schwerling, 2003]. In FFA, a force field is the sum of all the forces acting on or in an object.

The original physics and topology-oriented model of forces conceived each force comprising a force field as having magnitude and direction. Perhaps, in such a model, the sign of the magnitude of projection of each force vector on the vector between the organization and its goal state dictates whether the force helps or hinders achievement of the goal. Most practitioners choose to disregard this level of complexity and in general group forces into a few principal categories, such as "facilitating", "constraining" and "blocking" [Chronshaw and McCulloch, 2008], or "forces for change" and "forces against change" [Burnes and Cook, 2013] or "hindering" and "driving" forces [Schwering, 2003], or "facilitating forces" and "constraining forces" [Nicholas, 1989]. This paper elects to refer to forces as either "enabling forces" or "barrier forces" or simply "enablers" or "barriers" because one of the authors has found this terminology useful in the practice of applying FFA.

Figure 1 shows a generic, conceptual model of FFA. The presented concept focuses on forces that enable or oppose the achievement of some goal state. No magnitudes, timing or ordering is implied in this diagram. This diagram assumes some goal has been set, and there is a corresponding goal state associated with the goal. A total of *n* enabling forces are shown. Each enabling force helps move the organization from its current state to its goal state. A total of *m* barrier forces are shown. Each barrier force works against the organization moving from its current state to its goal state.

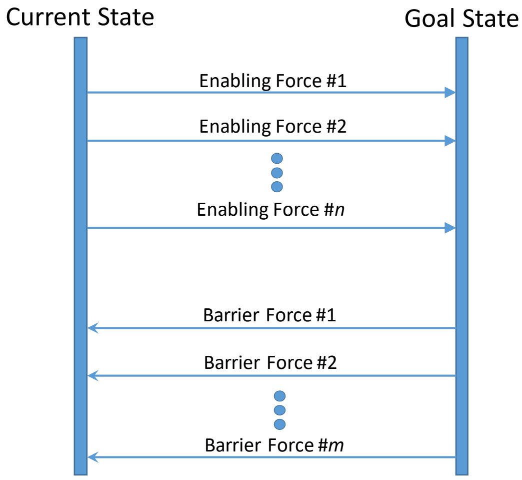

Figure 1: Generic Conceptual Model of Force Field Analysis

Using Force Field Analysis

Applying FFA is a well-defined and somewhat repeatable process. This section provides brief, high-level instruction for how an organization may apply FFA to help move toward a goal state. There are several steps to using force field analysis, beginning with defining the goal. These steps are described in Table 1. For each step, a description is offered as well as a number of recommendations. The steps are discussed in the context of a small set of participants (group) led by a facilitator.

Setting a goal and then using FFA to determine how to achieve that goal is often an iterative process. As individual forces relating to a top-level goal are analyzed, sometimes additional goals are set for overcoming or exploiting those forces. Other times the top-level goals are refined as a result of exploring forces. Many times a single force can be simultaneously viewed as both potentially helping and also hindering the achievement of a goal. For example, a senior executive enthusiastically championing a project is a force that can be leveraged to help recruit the most talented individuals to work on the project. On the other hand, that same advocacy can undermine morale if the senior leader micromanages and makes decisions generally delegated to project leadership.

FFA and Systems Engineering

FFA can be applied to systems engineering. There are many decision analysis methodologies used throughout systems engineering such as Multi-Attribute Utility Theory (MAUT) and decision trees that help select between already defined options. FFA helps identify the options in the first place. Eventually, if it is unclear which actions to prioritize, then established decision analysis methods can be leveraged to down-select. It is important avoid down-selecting without doing due diligence in identifying the possible alternatives.

The holistic underpinning of FFA makes an alignment with systems engineering natural, and there are examples where FFA is being used in a systems engineering context. FFA does appear in the systems engineering literature in very specific applications [Melsa, 2009; Santerelli, 2008], but broad guidance for how to use FFA to achieve systems engineering goals remains unaddressed so far in the systems engineering literature.

Table 1: FFA Steps and Recommendations

Step	Description	Recommendations
1. Define goal	Define the goal to achieve, including non-ambiguous and verifiable criteria for achieving the goal as well as restrictions.	• Have senior management contribute ideas and keep the group defining the goal small. • Appoint a facilitator – either someone within the organization who has experience or knowledge in goal-setting techniques or an external consultant with goal-setting expertise. • Have the facilitator work with senior management to help shape and fully define the goal, including what restrictions to place on the pursuit of the goal.
2. Define plan for achieving goal using FFA		
a. Identify enablers and then barriers	• Determine what forces are believed to be enablers, write them down, and then consolidate them. • Then determine what forces are believed to be barriers, write them down, and consolidate them.	• Encourage each participant to independently contribute at least one enabler. • Make a master list of enablers. • Consolidate similar enablers so that there is a unique set of enablers. • Discuss to group satisfaction so that all enablers in consolidated list are clear to all. • Repeat recommendation above with barriers. • Note that many techniques that can be used to elicit requirements can also be used to identify enablers and barriers. Examples are focus groups and interviews.
b. Select major enablers or barriers	Of all the identified enablers or barriers, select the top few that are to be considered in more detail.	• Make sure to select at least one enabler and at least one barrier. • Focus on enablers and barriers that if effectively leveraged or mitigated would significantly move organization toward its goal. • Do not be too quick to dismiss barriers as insurmountable. • Consider weighted voting or dot-voting techniques [Mindiply, 2017] to elicit group input.
c. Identify strategic actions	For the selected subset of enablers and barriers, determine what could be done to leverage enablers or overcome barriers.	• Repeat same process as was used to identify enablers and barriers. • As there may be multiple barriers and multiple enablers, the facilitator may wish to assign certain individuals a subset of the selected enablers and barriers to focus on. • Once again, compare inputs for redundancy and consolidate into unique set.
d. Select strategic actions to implement	Of all the identified actions, select the few that the organization should focus on.	• May be helpful to frame each strategic action as a cost/benefit proposition. • Repeat voting technique used to select major enablers or barriers.

The systems engineering strategy framework can be used to help supplement the use of FFA in systems engineering. It has been shown that prompting techniques, including brainstorming in categories, can increase the number of items elicited from a group [Browne and Rogich, 2001]. The classes and attributes described in the systems engineering strategy framework [Smartt and Ferreira, 2012] provide a set of categories and factors for guiding systems engineering strategic decision-making. Having this set as a base can aid in the brainstorming of enablers and barriers (step 2a from Table 1) and strategic actions (step 2c from Table 1). However, these classes and attributes are by no means comprehensive. Because of this, the authors recommend beginning with free-form ideation, in other words, brainstorming enablers and barriers to the given whole goal and then brainstorming through some or all of the factors posited by the systems engineering strategy framework.

The application of FFA in conjunction with the systems engineering strategy framework is best explained through an example application. There are many examples that could be explored for using FFA in systems engineering that could involve individuals or small groups tackling specific problems in systems engineering organizations. Examples of applications of FFA to systems engineering include maintaining up-to-date documentation for a system after a system undergoes a major maintenance or upgrade event, quickly growing systems engineering knowledge in junior engineers, and deciding whether and how to evolve to using MBSE to perform systems engineering within an organization. The MBSE example is explored in detail in this paper because it is complex, important and requires strategic thinking. While many systems engineers may not have faced such a problem, the approach can be emulated for other issues still requiring a strategic focus.

Example Application: Using Model-Based Systems Engineering (MBSE) for Systems Engineering for Prototype Effort

This section will discuss how to proceed through the steps in Table 1 with a systems engineering example. The example will address the decision process of institutionalizing the use of MBSE in an organization. The INCOSE 2025 Vision projects that by the year 2025, MBSE will become standard practice [INCOSE, 2014]. MBSE is defined as "the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases". [Zimmerman, 2014]. Delligati [2014] defines the three pillars of MBSE as modeling language, modeling methods, and modeling tools.

Despite its great potential, MBSE should be adopted carefully and deliberately as it involves a significant shift in how systems engineering is done. Friedenthal [2009] describes MBSE as a "cultural change" and cautions against making the transition to MBSE in an ad-hoc manner. The kind of formalized modeling required by MBSE is a skill that many systems engineers do not have experience with or training. In most cases, the adoption of MBSE requires training in modeling languages and modeling methods. MBSE tools also pose another set of challenges. The off-the-shelf software for MBSE can be expensive and often has a steep learning curve, even for those who understand modeling and are familiar with MBSE concepts. Friedenthal [2009] recommends pilot projects to validate an organizations' approach and better understand the opportunities and challenges.

One powerful, popular language used for MBSE is the System Modeling Language (SysML). SysML "is a general-purpose graphical modeling language for specifying, analyzing, designing, and verifying complex systems that may include hardware, software, information, personnel, procedures, and facilities. In particular, the language provides graphical representations with a semantic foundation for modeling system requirements, behavior, structure, and parametrics, which is used to integrate with other engineering analysis models" [OMG, 2017a].

SysML can greatly enhance the communication of information related to a system. SysML includes a series of viewpoints, each with defined semantics. These defined semantics aid in conveying information within an engineering team and with other project stakeholders. People familiar with SysML but perhaps unfamiliar with a system can quickly and efficiently understand the system. While SysML viewpoints can be constructed without specialized software, software tools exist that allow for managing systems engineering data in a SysML model. These tools allow for relationships (e.g., traceability) to be defined and maintained between various viewpoints such as requirements, architecture elements, and test points. Using these tools, generally changing information about an element in one view automatically propagates the changes across all viewpoints. This reduces the tedium and labor costs of maintaining the system documentation over the system lifecycle.

As an example, suppose a director of systems engineering wishes to make an informed decision about whether she will mandate the use of SysML and the creation of certain SysML artifacts as part of the organization's systems engineering process tailoring guidelines. The guidelines are traditionally updated every other year, and decisions impacting the content of the next revision must be made within the next 8 months. The director wishes neither to prematurely institutionalize SysML without fully understanding the challenges nor delay in adopting SysML if it is worthwhile for some of the projects the organization undertakes. She needs good information. She needs the organization to make a serious attempt at using SysML, and use the lessons learned to inform her decision to mandate the use of SysML or not. She decides to adopt Friedenthal's [2009] recommendation and proceed with a pilot project.

One type of pilot project that organizations may elect for the use of SysML is the development of a prototype system. Prototype development projects provide good opportunities to experiment with novel processes. One benefit of prototype development efforts are that often they have a relatively compressed schedule. This is advantageous because systems engineers can gain an understanding of how to use SysML over the whole development lifecycle in a relatively brief timeframe. In months, they can develop requirements, a systems architecture, test artifacts, and the various traceability and dependency relationships between these artifacts, all using SysML. Often prototype development projects are less formal than engineering efforts for more mature systems, and this allows for the flexibility to experiment with SysML. In some organizations, prototype development is done by special groups of engineers who have considerable flexibility for tailoring processes. Engineers, including systems engineers, who work on these projects are often open to innovation, both in technology and process.

Step 1: Define Goal

An organization wishing to embark on a pilot project using SysML would need to allocate appropriate financial resources and time in the prototype project. The financial resources include paying for: (a) direct costs of training programs for using SysML and using specialized SysML tools, (b) employees' time taking the training, (c) the SysML tool-related costs (license costs and/or computer resource upgrade costs to meet required hardware standards for SysML tools, installation costs), and (d) process tailoring to direct the use of SysML on the pilot project. There may also be a need to hire one or more employees who specialize in SysML and using specialized SysML software to consult and lead the organization. Before embarking on such a pilot project, organizational leadership should seek to understand these costs in their entirety and weigh whether the pilot project is likely to provide information worthy of its costs. The time considerations should allow for: (a) delays related to employees training on SysML and the related tools, (b) delays as employees learn the tailored organization processes related to using SysML, (c) delays related to acquiring, maintaining, and troubleshooting software and information technology issues related to the SysML software, and (d) possible schedule acceleration gained by the ease of documentation maintenance using SysML.

The MBSE goal is to be formulated as a Whole Goal, and Whole Goals include restrictions. Restrictions should address impacts on technical quality, cost and schedule. Systems engineers using SysML should not shortchange the usual level of systems engineering rigor applied on a prototype development project because they are devoting time to learning new methods, tools and techniques associated with SysML.

The Whole Goal statement is: "Enable the director of systems engineering to determine whether to mandate the use of SysML in the organizations' systems engineering process tailoring guidelines for projects in time for the next iteration of the tailoring guidelines. Restrictions include: (a) SysML must be used on a pilot project, (b) sufficient funds must be expended on SysML use in the pilot project to reflect adequate rigor, (c) the application of SysML shall not increase project costs or schedule to a point of endangering the viability of the pilot project, (d) SysML tools must be acquired and used, and (e) at least 4 pilot project participants must be trained on SysML and SysML tools".

In this example FFA will be used to help ensure adequate rigor for the pilot project, and to ensure that a serious enough foray into SysML is undertaken that lessons learned will be valuable in making the institutionalization decision.

Step 2: Define Plan for Achieving Goal Using FFA

Once Whole Goal statement is defined, one can identify enablers and barriers.

Step 2a. Identify enablers or barriers

Assume the free-form brainstorming identified the following enablers:

> E1: A handful of the systems engineers are from the software organization and have extensive experience using object-oriented modeling (OOM) to develop software. This knowledge of modeling and related tools can be built upon to expedite organization's knowledge of using MBSE and SysML.
>
> E2: The Vice President (VP) of Engineering champions the use of model-based approaches as he has seen them successfully applied in a previous organization where he was a manager.
>
> E3: The organization participates in process improvement initiatives and seeks to demonstrate innovative and efficient processes to accreditors.

And the following barriers:

> B1: The research and development (R&D) group leading the prototype development effort has limited patience for any delays caused by systems engineering processes.
>
> B2: The systems engineering organization has very limited leftover training budget after providing basic process training and training on the legacy object-oriented requirements management tool.
>
> B3: While there are a few systems engineers with OOM experience, the majority of the systems engineering group employees have no experience with OOM.

Basic brainstorming such as what is described above is a very efficient way to identify enablers and barriers, and is helpful for pinpointing opportunities and challenges specific to the goal. However, the set of enablers and barriers identified may not be quite complete as these are simply the ideas that emerge at the time from the participants. It may be helpful to examine a set of common enablers and barriers that pervade many systems engineering strategic decisions. The systems engineering strategy framework [Smartt and Ferreira, 2012] can be used to help enhance the depth and rigor of the process. Review the classes and attributes and determine if they bring to mind additional important factors.

After obtaining the initial set of enablers and barriers, compare those to the classes and attributes of the systems engineering strategy framework. It is reasonable to expect for any goal, only a small subset of the classes and attributes in the systems engineering strategy framework will relate to the goal strongly enough to add them to the set.

To show how the systems engineering strategy framework may be applied, an example is given where the enablers and barriers identified through brainstorming are traced to classes and attributes in the framework. E1 can be traced to employees' skills, levels of experience and skill levels, while E2 and E3 can both be traced to the organization's propensity to adopt new processes and approaches. B1 can be traced to level of alignment of the systems engineering organization with other organizations within the larger organization. B2 can be traced to the organization's investment propensity, and B3, like E1, also traces to employees' skills, levels of experience and skill levels.

Examining the classes and attributes of the systems engineering strategy framework triggers a new idea: that is the potential benefit of teaming with external partners. Suppose the local university's systems engineering curricula includes a course in MBSE, and as part of that course, students are taught how to model using SysML. Bringing in one or two students from this academic program as interns to help in the formal modeling will simultaneously yield multiple benefits.

(1) It will infuse the systems engineering team on the pilot project with some additional expertise in SysML,
(2) It will allow the students to apply their academic knowledge to a real-world problem, and
(3) It will allow the organization an opportunity to make longer term or full-time job offers to students who can effectively apply what they learned in their academic program to real-world projects.

E4 is to hire local students familiar with MBSE and SysML through their academic training.

These enablers and barriers are shown graphically in Figure 2.

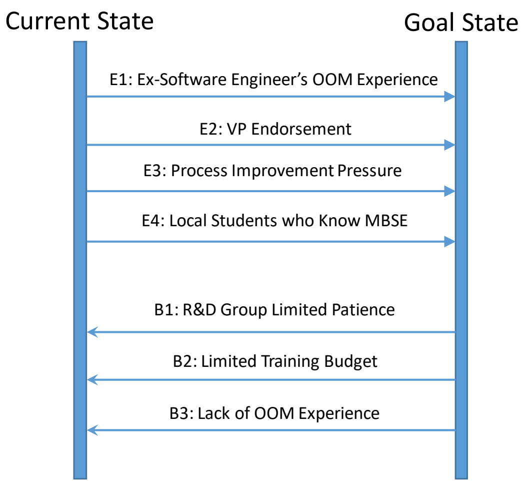

Figure 2: Enablers or Barriers for SysML Pilot Project

Step 2b. Select major enablers or barriers

It is most beneficial to focus on a few enablers and/or barriers. The focus should be on enablers that are the most impactful and barriers truly standing in the way of achieving the goal. In the example above, the three enablers that are most impactful are E1: Software Engineers' OOM Experience, E2: VP Endorsement, and E4: Local Students who Know SysML. The OOM experience will expedite the learning curve for SysML and VP has financial resources and political capital that can be used to help achieve the goal. The local students who know SysML serve as a great potential resource. The culture of process improvement may ultimately increase the likelihood of the organization embracing

MBSE if it appears promising, but it is unclear how to do something to leverage that enabler. Therefore, it is not recommended to focus on E3.

In this case, all three barriers are significant, but the two that the organization may opt to mitigate are B1: R&D Group Limited Patience and B2: Limited Training Budget. The R&D Limited Patience if ignored could degrade morale and limit innovation on the pilot project as well as potentially create future resistance toward using pilot projects to explore new systems engineering processes. Further, the limited training budget limits the depth of training and, or the number of people that can be sent to formal training. The lack of modeling experience may itself be mitigated by the successful attainment of the goal, and therefore it is not recommended to focus on B3.

Step 2c. Identify strategic actions

In the previous step, a decision was made not to take action to specifically address E3 and B3. Therefore, the enablers and barriers for which action plans will be devised are: E1, E2, E4, B1 and B2.

E1: Ex-Software Engineer's OOM Experience: For this prototype development project, the systems engineering team should include at least two people with OOM experience, even if they have no experience with systems similar to the prototype system. At least one of these individuals needs to be in a leadership position so as not to be overruled by those with less experience and confidence in model-based approaches.

E2: VP Endorsement: The VP endorsement may be the key to achieving this goal. The VP can help with all the other enablers and barriers. He may be able to help negotiate with lower level management to assign the systems engineers with the OOM experience to the project, he may be able to supplement existing budgets for either training or systems engineering labor on the prototype efforts.

E4: Local Students who Know MBSE: If there is not an established pipeline for recruiting students from the local systems engineering program, establish one. Make connections with professors, understand the alignment with the curricula and the needs of the organization, and use these connections and knowledge to help identify the best interns for the organizations' needs.

B1: R&D Group Limited Patience: In addition to upper-management endorsement, ultimately it is necessary to obtain buy-in from some of the technology experts in the R&D team. Someone influential among their peers who does not necessarily come from even a systems engineering background needs to be open to SysML and what it can do to help expedite innovation. This is where knowledge of the personalities of key employees becomes pertinent.

B2: Limited Training Budget: The organization may have to find innovative ways to afford the training necessary to obtain a large enough quorum of systems engineers who are SysML literate to execute the pilot project. In many systems engineering organizations, employees are motivated to enhance their credentials and often are willing to invest some personal time to do so if the rewards are adequate. The OMG [2017b] offers certifications in SysML, and the organization may wish to propose a time sharing arrangement with employees to help them obtain such certificates. The organization may wish to propose to pay for the direct training costs for SysML as well as administrative costs to obtain a certification. The organization may wish to compensate some of the time and ask employees to contribute the rest of the time as personal time. To the degree practical, the organization may offer flexible scheduling so that employees can make up some or all of the time spent pursuing the SysML certificate without having to expend vacation time. This could constitute a win-win scenario for both organization and employee.

Step 2d. Select strategic actions to implement

It may make sense only to implement a subset of the strategic actions, and the rationale for which subset to implement is very goal-specific and context-specific. For each action, the likely costs and benefits should be taken into consideration. Costs can be direct costs to the project, overhead costs to the organization or intangible costs such as expending political capital to get the endorsement of executive leadership. While the VP endorsement has huge potential benefits for the SysML adoption goal, it may divert the VP's attention and resources from other goals of interest to the systems engineering organization, such as funding to modernize the organization's systems engineering processing guidelines, or attaining additional office space with an adequate number of conference rooms to allow systems engineers to collaborate more effectively.

Benefits include the degree to which the action helps achieve the goal but also any tangential benefits that come from the strategic action. Of the example strategic actions identified, the action to leverage local students with SysML knowledge is potentially the one with the most side benefits. These benefits would include establishing a potential pipeline of new hires who are knowledgeable about modern systems engineering processes, techniques and tools, and forming a strategic relationship with a department that may be able to customize training for the organization.

Conclusion

This paper describes how to apply FFA as a method to facilitate achieving goals as part of a systems engineering strategy, and includes an example related to adopting SysML on a pilot project. In summary, FFA is an examination of factors (called "forces" by Lewin) that are driving an entity, organization or individual, toward or away from achieving a particular goal. These "forces" are respectively termed "enablers" and "barriers". FFA facilitates the identification of enablers and barriers, and it is that inventory of forces that provides scaffolding for two planning questions: "What can we do to better exploit the enablers?" and, "What can we do to mitigate or eliminate the barriers?"

Both goal formulation and the use of a defined process to derive and select specific actions to help achieve the goal are discussed. Information is provided about to how to leverage work done to date on the systems engineering strategy framework in order to add rigor and completeness to the process. It is expected that organizations will struggle through the steps of the process when confronted with the real-world ambiguities inherent in such strategic planning, and there may be multiple iterations and periodic refocusing of goals. An example involving adoption of MBSE is provided in this paper and may serve as a guide for the process. On a final note, FFA provides a powerful, systematic and scalable methodology that helps identify actions an organization can take to achieve a goal. Nonetheless, applying FFA to a hard problem is usually hard work. Individuals and organizations need to be cognizant of this and allot the time, resources and mental energy if they hope to achieve success.

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