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PRINCIPLES OF SOCIOLOGY IN SYSTEMS ENGINEERING

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Abstract
Systems engineering involves both the integration of the system and the integration of the disciplines which develop and operate the system. Integrating the disciplines is a sociological effort to bring together different groups, often with different terminology, to achieve a common goal, the system. The focus for the systems engineer is information flow through the organization, between the disciplines, to ensure the system is developed and operated with all relevant information informing system decisions. Robert K. Merton studied the sociological principles of the sciences and the sociological principles he developed apply to systems engineering. Concepts such as specification of ignorance, common terminology, opportunity structures, role-sets, and the reclama (reconsideration) process are all important sociological approaches that should be employed by the systems engineer. In bringing the disciplines together, the systems engineer must also be wary of social ambivalence, social anomie, social dysfunction, insider-outsider behavior, unintended consequences, and the self-fulfilling prophecy. These sociological principles provide the systems engineer with key approaches to manage the information flow through the organization as the disciplines are integrated and share their information. This also helps identify key sociological barriers to information flow through the organization. This paper will discuss this theoretical basis for the application of sociological principles to systems engineering.

Keywords
Systems engineering, system integration, discipline integration, specification of ignorance, social ambivalence, social anomie, social dysfunction, insider-outsider behavior, unintended consequences, self-fulfilling prophecy

Introduction
Systems engineering is responsible for integrating the various disciplines within an organization to develop or operate a system. This aspect is a parallel aspect with system integration which involves understanding the system's integrating physics. If you understand the system, but not the organization structure and interrelationships you may never get the system developed. If you understand the organization but not the system's discipline and integrating physics, the system will not work. Systems engineering must deal with both aspects to design an elegant system.

Discipline integration is a highly sociological function and brings in aspects not traditionally thought of as engineering. These sociological aspects are essential as complex systems are developed by complex organization (the organizations are complex social systems). The systems engineer must understand how the organization is structured, how communication flows, and how information about the system is maintained. Information maintained within the organization is not always readily identified in the system design, managing this is a crucial role of systems engineers. Disciplines are reservoirs of information, information which they generate and maintain. The systems engineer manages the channels between these reservoirs ensuring the right information is provided to the right discipline when needed. Systems engineering applies many sociological functions in the development or operation of a system.

Opportunity Structures
Opportunity structures provide pathways for individuals advancement toward social goals in a social system. (Merton, 1996, pp. 153-161) Systems engineering is concerned with information flow about the system through the

organization. The opportunity for advancement of system design and operations ideas is an important social aspect of engineering. Systems engineering provides appropriate opportunity structures for the maturing of these design concepts and ideas as part of discipline integration. These structures include technical review forums (such as status meetings separate from decision making structures), task teams, working groups, communities of practice, etc. where new ideas can be explained, discussed, challenged, and matured leading to a fully formed idea for the formal decision making process. Note, that decision boards are idea filters, not opportunity structures. These boards select ideas that have been matured to the appropriate point for selection and they stop more ideas than they approve as the perform their selection as part of the decision making process. The opportunity structures provide the structure within the organization for new ideas to be developed and vetted, maturing them to the point where they can be discussed as an option by the decision board.

Systems Engineering Role-Sets

The systems engineer has a set of roles within the organization. This role-set (Merton, 1996, pp. 44, 113-122) includes system expert (in system interactions), system analyst, discipline integrator, team leader (study teams, task teams, etc.), advisor (to the program manager, chief engineer), and employee (to line management). These are not different roles conducted by the same individual but a set of roles associated with the position of systems engineer within the system design or operation.

System Terminology

Consistent use of terminology is important within the sociological function of systems engineering. Terms communicate ideas within an organization and can develop specialized meaning within certain cultures. Systems engineering ensures that terms are used with consistent and recognized (agreed to) meaning. Using different terms for the same meaning creates confusion in the organization and can lead to unanticipated system design or operation errors. Similarly, having a single term represent different meanings in different contexts also leads to organizational confusion and system design or operations errors. Systems engineering should avoid both situations that can occur in discipline integration. The focus is not on changing the discipline terminology by translating the various discipline terminologies so that a common understanding of the system is reflected in terminology at the system level.

The mathematics of the engineering solution provides an integrating medium of the discipline contributions for systems engineering. Mathematical solutions are built on various contributions by the differing disciplines. The mathematics captures and retains these contributions in the solutions. They are not lost but form an essential part of the engineering solution. As such, the mathematical relationships provide the systems engineer a mechanism to understand and measure the balance of a system, translating the discipline terminology through the mathematics.

Specification of Ignorance

Understanding of system interactions, sensitivities, and uncertainties requires application of sociological specification of ignorance. This is defined as “the express recognition of what is not yet known but needs to be known to lay the foundation for still more knowledge” (Merton, 1996, pp. 51-56) of the system. Systems engineering needs to know what is not understood about the system as well as what is understood. This fosters system analysis to gain understanding of these interactions, sensitivities, and uncertainties that are not defined. This also supports systems engineering identification of unknown unknowns as the understanding of the system expands. Sociologically, analysis is not conducted on areas that are believed to be known or areas that are not known to be unknown. Practicing the specification of ignorance enables the system engineer to identify areas that may otherwise be overlooked within in the organizational culture.

Socially Expected Durations

Socially expected durations play a big role in how people within the organization behave and react to the progress on the system development or operation. These expected durations are not actual durations and can be quite different. There are three kinds of expected durations: Structural or institutionally defined (socially prescribed) expectations; collectively expected; and patterend temporal expectations. (Merton, 1996, pp. 162-169)

Socially prescribed durations are the formal system schedules and timelines. Organizational authorities responsible for the systems establish these formal system schedules and timelines that engineers within the organization recognize. Collectively expected durations are a second type and are uncertain in terms of being able to specifically write them down. They are the collective attitude of a development organization or discipline in how they anticipate the development to proceed. Systems engineering is attuned to differences in the prescribed and collectively expected durations. These can indicate problems with the schedule and may indicate that an overly ambitious schedule has been established based on experience. There should be good engineering rationale associated with the formal system schedule with agreement from the disciplines that they can achieve the durations. The opposite can also occur, where the prescribed schedule is much longer than the collectively expected schedule. This can indicate problems in equipment availability, skills availability, funding availability, etc. This can also indicate the system is not achievable when needed which keys a review of the projects viability. The third kind of expected duration is patterned temporal expectations. These types of durations occur in areas such as contracting, business transactions, reorganizations, etc. There is an expectation of how long an agreement or transaction should take to be finalized based on cultural history and experience.

Socially expected durations drive how people behave within the organization. If they expect a short time frame, they may accelerate contributing efforts. If they expect a long time frame, they may slow down or procrastinate contributing efforts. Systems engineering ensures that the contributions provided by the disciplines are made in a timely manner maintaining a balance in the organizations effort as it progresses on the system schedule.

Cultural Subsets

Part of the complication of discipline integration is the cultural subsets that exist for each discipline. Each discipline contains a unique set of understandings and terminology for their discipline. Often different terms are used for similar, not necessarily the same, meanings. The same term may also be used for different meanings. Note that within the discipline the meanings are consistent but across the disciplines they are not. Systems engineering must translate the differing cultural meanings into a consistent terminology and understanding across the entire organization. Within each discipline, various cultural aspects can also make discipline integration challenging. The different disciplines typically have different team structures or processes and may use team structures or processes in different ways or view the significance of a team structure or process differently. Systems engineering functions to create a blended team structure across the disciplines where communication and information can flow without misunderstanding in meaning or significance of an activity.

Manifest and Latent Social Functions

Both manifest and latent social functions will be present in discipline integration. (Merton, 1957, pp. 60-69) Manifest social functions are defined as “objective consequences contributing to the adjustment or adaptation of the social system which are intended and recognized by participations in the social system” (Merton, 1996, pp. 87-95). Written norms of conduct which are adhered to by those in the organization (adherence is the important distinction) are an example of manifest social functions. Unwritten norms which are adhered to by those in the organization are also manifest social functions. Latent functions are defined as “those [social functions] which are neither intended nor recognized.” (Merton, 1996, pp. 87-95) These are difficult to identify and are not clearly seen by those in the organization. Organizational biases against certain solutions or approaches can be a latent social function. These can lead to positive or negative system impacts yet no one in the organization recognizes the bias. The result of the organizational actions can demonstrate the bias against an aspect. The systems engineer must be alert for these effects and work with organizational line management and program management to address manifest or latent functions which have a negative (limit or defeat) impact on the elegance of the system design or operation.

Social Dysfunctions

Social dysfunction is “any process that undermines the stability or survival of a social system” (Merton, 1996, pp. 96-100). Systems engineering helps to mitigate dysfunctions that can cause information about the system to be suppressed or inaccurately communicated. These dysfunctions are a risk factor for the system and can greatly affect the ability of an organization to accomplish a given system design or operation. Note, that innovative approaches to accomplishing a system can be very disruptive to organizations sociological values. This can mean that a given organizational culture is not able to develop the system which embodies values contrary to what the organization has come to believe as most important. Innovative system approaches often entail the formation of an entirely new organizational structure and culture with a different view on what is most significant in the system. Examples can be found in various industries including the computer industry (mainframe vs networked workstations), heavy equipment industry (steam driven systems vs hydraulic systems), medical practice, etc. (Christensen , 2003) Automation of previously manual operations is a current topic in the United States culture (i.e., anxiety toward drone applications).

Social Ambivalence

Sociological ambivalence is an “incompatible normative expectation of attitudes, beliefs, and behavior assigned to a social status (i.e., position) or a set of statuses in a society”. (Merton, 1996, pp. 123-131) An ambivalence can be created if a discipline or position within the organization is confronted with conflicting norms. Manifest and latent functions can lead to these conditions at times. This condition can pose a threat to the system's success. There are six (6) types of sociological ambivalence (quotes in this list are taken from Merton (1996, pp. 123-131):

1. "Inherent in the social position"
   Government employee relationships with contractors are an example where government ethics demands disinterest while social etiquette requires personal interest.

2. "A conflict of interests or values"
   These may arise when a person is a member of two different organizations such as in a matrix organizational structure or when a person is working two projects. If the normative values are different the person can become socially ambivalent. For example, when one project norm is to do what it takes to solve a problem conflicts with the time agreed to spend on another project. A conflict in time priority arises where one cannot satisfy both norms. These can also arise between organizational values and values from a person's life outside the organization.

3. "Conflict between roles associated with a particular" position
   These are conflicts in cultural norms that occur inherent to a given job position. These can occur in discipline integration where a representative to the system team may find oneself in conflict between norms of the system team and norms of their discipline team. Another example may be in procurement, balancing the norms of the procurement office with that of what the program views as necessary for success.

4. "Contradictory cultural values"
   These can be a risk to the system and occur when different cultural values collide. For example, an emphasis on high reliability can conflict with the need for techniques seen as not credible. This takes special effort to determine the engineering basis for the view that the technique is not credible in the specific context of application, and that the engineering basis that the technique will improve reliability. As discussed below, mathematics provides an integrating function for social functions and should be used in evaluating these types of conflicts. Look for engineering representations, not subjective logic.

5. "The disjunction between culturally prescribed aspirations and socially structured avenues for realizing these aspirations"
   This illustrates a disconnect between social expectations and the structure to achieve these expectations. An example is when a quick change is needed in the system design or operation and the organizational structure does not support a quick assessment and implementation of the change. The engineer is faced with either allowing a larger impact to the system later or moving ahead of approval with a change. Systems engineering is to ensure that the decision-making structures are efficient and that mechanisms are in place for the types of disjunctions in this example (e.g., Reclama processes discussed below).

6. That which "develops among people who have lived in two or more societies and so have become oriented to differing set of cultural values"
   This occurs when an engineer worked in different disciplines or supported projects with very different cultural values. The varying cultural values experienced can lead to ambivalence to cultural values in the current system that conflict or contradict what has been successful in the engineer's past. This can lead to a strong disinterest in the social structure of the system development or operation. These types of issues should be brought to line management or project management (at the appropriate level) to address. It is important that the members of the organization have an agreed to set of values or sociological dysfunction can develop within the sociological structure of the organization.

Sociological ambivalence can lead to a failure to deal with or possibly to acknowledge conditions that affect system reliability and success. Systems engineering must be aware of these conditions when they occur in the organization and seek to find a new balance for the norms. This may involve the precedence of conflicting norms elevating one as more prominent to resolve a conflict or finding a common understanding that balances the norms, and addressing the concerns that may be suppressed in the ambivalent situation.

Social Adaptation and Social Anomie

There are five (5) types of individual adaptations to the social structure. These adaptations cover the full range of individual responses to the organizational structure and project goals. (Merton, 1996, pp. 132-153) and (Irmak & Çam, 2014, pp. 1297-1305) These can be either healthy or unhealthy depending on the specific context of the situation. The systems engineer interest is in how these different approaches affect the flow of information about the system. As individuals feel less supported by the organizational and project structures they have varied responses to trying to achieve the project goals. Social Anomie is the most extreme condition discussed briefly at the end of the list of social adaptations.

1. Conformity
   Most people seek to conform to the cultural norms and the social structure to achieve these norms. They will try to stay within these bounds as they work in the organization.

2. Innovation
   Individuals caught in a conflict between the cultural norms and social structure may try to create a new path through the social structure. This typically involves violating some minor cultural norm or organizational constraint to resolve the conflict (or organizational pinch) that they are in. An example may be in skipping a level in the chain of command or bypassing an approval cycle to move forward. There are many more creative ways that people may find to move forward in satisfying a cultural norm that the social structure is not facilitating. Social structure in this case would include the formal approval cycle (e.g., decision making boards).

3. Ritualism
   In some cases, the frustration in conflicts can lead to an abandonment or reduction in importance to achieving a cultural norm leading to a ritualistic following of the organizational structure processes. This can be dangerous to the system as ambivalence has developed and conflicts in the system design or operation may not be identified as discussed above.

4. Retreatism
   Occasionally an individual will retreat from both the cultural norms and the organizational structure. A person who is in such an ambivalent situation simply withdraws from significant participation in the system development or design. When this occurs, the person should seek a different position in the project or with another project where the conflict they have encountered does not exist. These cases should be discussed with line management or project management at an appropriate level. Systems engineering is focused on the success of the system. When these deep sociological conflicts develop, line management is primarily responsible to help the individual deal with the conflict. Systems engineering is responsible to ensure the conflict does not indicate an issue in organizational culture values or structure that needs to be addressed.

5. Rebellion
   This is the most radical of the responses to sociological anomie situations. Rebellion is a strong form of social dysfunction attempting to bring about a new social structure within the organization. This can occur in cases were an organization views the success of system based on different values than are required for the system in application. This can occur when a traditional organization attempts to adapt to a disruptive technological approach. As discussed above, this may mean the organization is not suited to the system development or operation. (Christensen, 2003)

An extreme sociologically ambivalent context leads to sociological anomie. In this case an individual in the culture can become normless or rootless.(Merton, 1996, pp. 132-152) A no win situation has been perceived where an individual moves outside the organizational structure, opposes the organizational norms, to achieve what the sociological culture call for and the organizational structure is preventing. This imbalance occurs when the emphasis on success-goals of the system are much greater than the emphasis on the institutional means to achieve these goals.

Engineering Reclama

The engineering reconsideration process (sometimes referred to as a reclama process) is one means by which to accommodate individuals caught in these difficult social norm conflicts. The systems engineer should ensure that an effective reconsideration path is available and impartial to the social norms. The use of line management can be an avenue unless the line management is driven by the same cultural norms (both manifest and latent) as the system development or operation organization. In these cases, other pathways (external organization, external arbiter, etc.) will need to be found for relief of the anomie generating situations. This is important to the system success as major failures have occurred in systems where effective reconsideration paths were not available or went through a chain driven by the same cultural norms that generated the conflict. (e.g., see CAIB,(2003) or the Rogers Commission Report (1986)).

Self-Fulling Prophecy

One possible response to social ambivalence, dysfunction, and anomie is in the self-fulfilling prophecy.(Merton, 1996, pp. 183-201) This sociological concept deals with the expected behavior of a group. If the culture defines a group as socially different, the organization can establish expectations and ascribed motives to the group, whether they accurately describe the group or not. The organization interprets the actions of the group in terms of the organizations expectation and ascribed motives. Thus, no matter how the group behaves, their actions always "confirm" the expectations of others in the organization. This form of prejudice or bias can lead to serious limitations of the system and certain disciplines, organizational units, or engineering approaches can be shunned by the organization even when a needed and positive contribution is offered. Sociologically, "the self-fulfilling prophecy where fears are translated into reality operates only in the absence of deliberate institutional control." (Merton, 1996, p. 200) Thus, systems engineering needs to be aware of these types of bias and ensure that the organization controls the social biases that may be expressed. Testing these biases against a sound engineering basis is a good method to help identify and control this bias. This is one sociological reason why the engineering reconsideration system may need to be outside the development or operational organization.

Social Groups

Different sets of knowledge exist in different social groups (i.e., disciplines or organizations). This is not just technical knowledge but all kinds of cultural knowledge including history of various efforts. Access to knowledge is free in most societies, but it is not practical or possible for a single individual to have all knowledge. This leads to the formation of small groups of knowledge within a society. Within engineering, these are the disciplines. As systems become more complex, the ability to contain all knowledge of the system by a single individual is quickly surpassed and a larger group is needed. Thus, for most system developments or system operations, the knowledge of the system is contained by the organization and not just an individual. This is a natural sociological function and can be a very positive social structure when used cooperatively.

Sometimes, though, the differences in beliefs brought about by the different knowledge sets in each group can lead to contradictions in beliefs between the groups. These can be beliefs on which configuration or version is best, which approach will or will not work, and even how the project should be managed. When this happens the communication between the groups can break down and a strong distrust between the groups can develop. In its extreme, this leads to a questioning not of why the belief of the other group is wrong, but a questioning of what is their motive to bring such a "palpably implausible" belief statement into the discussion (Merton, 1996, pp. 205-222). This social polarization greatly hinders the progress on the system and can defeat the elegance of the system as effort is spent managing social conflicts within the organization rather than attention to elegant solutions for the system. Polarized political beliefs are a good example of this phenomenon.

Social polarization leads to functionalization of thought interpreted only "in terms of its presumed social or economic or psychological sources and functions." This can lead to an exclusive view of information or knowledge contained by a group (i.e., "insiders") with others viewed as "outsiders" (Merton, 1996, pp. 241-263). This also sets up a self-fulfilling prophecy about those outside the group being unable to understand the knowledge possessed by the insiders. A monopolistic view of knowledge contained by the insiders is maintained breaking down communication altogether with outsider groups. The belief becomes one that you must be an insider to understand the knowledge or situation. The outsider groups are assumed to have different beliefs even when this is not true (Merton, 1996, pp. 241-263).

Systems engineering takes action to mediate these different beliefs and to foster trust within the organization, among the disciplines, and with external organizations. Openness to discussion and allowing expression of beliefs to be made is important in this difficult context. Seeking points of commonality is a starting point to bring the groups to a common understanding. Note, there are individuals who may not be able to move past the distrust due to their own personal experiences, relationships, etc. This can also occur at the organizational level indicating that a group or organization may not be compatible for some reason. Changing a group or groups, if possible, can be a solution if an alternative is available. Normally competing organizations attempting to work together can experience this very strongly.

Minimize Unintended Consequences

The systems engineer must manage the sources that lead to unintended consequences. Unintended consequences are based on human action or inaction resulting in unanticipated outcomes. The systems integrating physics do not fail; we simply do not always recognize the consequences of our actions/decisions. Robert Merton (1936) developed five (5) sources of unintended consequences that provide a framework to understand and manage these difficult results.

Ignorance

Ignorance is a limited knowledge of the problem leading to unexpected performance (i.e., anomalous) or failure of the system. Failing to understand the system's interactions within itself and with its environment is a major source of ignorance leading to poor (though not realized) design decisions. Often the engineering and science is not well understood and the system models do not capture these interactions. The systems engineer must realize where knowledge is lacking and manage the risks, uncertainties, and sensitivities to these unknown or poorly understood interactions. Conducting tests, where possible, provides a method to reduce the ignorance in system interactions. Validation of models is also a crucial method to reduce the uncertainty in the system models used for design and operation.

Another form of ignorance is on the effect of the system, its fabrication, or its operation in the environment or local cultures. This can lead to effects which limit or eliminate design, fabrication, or operational configuration options. This requires a good understanding of policies and laws (e.g., Environmental Protection Agency regulations).

Historical Precedent

Historical precedent (i.e., confirmation bias) is characterized by expecting previous efforts to result in the same outcomes. This bias often overlooks the changes that may make the previous efforts inapplicable. This is frequently encountered when using "heritage" components in similar applications. These components will need to be re-qualified for the new applications and new environments which often leads to design changes. NASA cost models are generally based on historical precedents and are frequently inaccurate due to the presence of this unrecognized bias. New methods, procedures, and materials change the basis of the cost models but were not anticipated in the previous efforts and are not explicit in the model structure. This bias can be mitigated by recognizing the differences in the system application and environments from previous uses and accounting for these differences in the design, budget, schedule, and operations.

Error

Errors are simply undetected mistakes in the design or operation of a system. This encompasses mistakes in calculations, mistakes in communications, and working from habit. Error is different from ignorance in that the correct solution is known but not implemented. The systems engineer should recognize the sources of error and develop checks for these. Verification and validation are part of the checks for errors in design. Model validation plays a crucial part in ensuring that the model accurately represents the systems integrating physics or logic (software) of the system. In complex designs, independent evaluations provide a check against errors in the system. This is often done for critical software.

Communication errors are a significant concern in organizational information flow. The systems engineer should ensure that the correct information is provided to the designers and decision makers for the design to achieve the intended consequences. If inaccurate or incomplete information is allowed to propagate through the organizational structure, design or operation decisions can be adversely affected resulting in unintended consequences.

Short-Sightedness

Short-sightedness (what Robert Merton called the "imperious immediacy of interest" (1936)) is focusing on near term consequences and ignoring long-term consequences. Government driven projects are particularly susceptible to this type of unintended consequence. This can lead to budget, schedule, and performance issues or failures. Budget cycles are annual and the consequences of the budget in 5 or 10 years are often not credibly considered (since situations in the country will be different then). This leads to an emphasis on next year's budget at the expense of the budget in the next decade. Although not intended, design decisions are driven by near term cost savings which could increase long term costs. Accountability in the Government system reinforces this and it must be actively and consciously addressed by the systems engineer in the all phases of the system design and operation. The systems engineer will also need to work with program management and organizational management to keep this tendency in check. Part of balancing an unintended consequence is to have visible and explicit metrics and cost data to provide a current view of the long term consequences.

Schedule can also be driven by shortsightedness, by making decisions to achieve near term milestones that may delay future efforts by months or years. Mission dates are often well known, providing a clear and explicit target of the future consequences. Planetary missions, in particular, have "must achieve" dates that keep the near term decision drivers in check. Understanding the relationships of today's decisions to future limitations is a major factor in ensuring the system effectiveness in achieving its intended consequences.

System performance is well understood if the System Application Context is well defined. This provides a guard against making near term over longer term performance. System performance can be adversely affected by budget and schedule decisions and the consequences of these decisions needs to be clearly understood as part of the decision. There can be a tendency to look past these consequences leading to a system with reduced capability or failure to meet the mission objectives. The systems engineer is responsible for ensuring these consequences are identified and discussed as part of the decision process. Without this understanding, it is easy to reduce or remove major system capabilities unintentionally.

Cultural Values

Cultural values can lead to cultural bias regarding what can and cannot happen. Cultural values exist in every organization. Many of these values are positive and help the organization be successful in its execution of system design and operation. Cultural values, though, can also create blind spots for the organization. If the organization believes that a consequence will not occur, then it will not guard against the consequence (if negative) or pursue the consequence (if positive). The Columbia Accident Investigation Board (CAIB, 2003) and the Roger's Commission (1986) both cited strong cultural biases leading to the Columbia and Challenger accidents. The organizational culture supported the belief that the failure sources were not credible and did not adequately protect against these failures, resulting in the two disasters. The systems engineer must first recognize the organizational culture and then protect the system design from any cultural bias that may exist. A key to this is considering consequences with objective facts, recognizing uncertainties and sensitivities, and providing systems integrating physics-based or mathematically-based answers. Cultural bias can be stated more subjectively and may not be based on facts directly relevant to the current system. This difference must be understood to avoid culturally induced unintended consequences.

There are two cognitive biases that should be considered: confirmation bias and over confidence. (Roberto, 2009) Confirmation bias seeks to confirm pre-existing understanding (and so avoids specification of ignorance). This bias leads to a focus that what we already know is right. The self-fulfilling prophecy (Merton, 1996, pp. 183-201) is a large factor in these situations where no matter the outcome of a situation, the situation is always viewed as confirmatory to the cultural belief system. This can create significant blind spots in system development and operations. Opportunity structure having diverse opinions can mitigate confirmation bias. Over confidence leads to a failure to recognize important information about the system. Signs of emerging issues can be missed and a failure to explore unknown phenomena is the result. This form of bias also results in a failure to specify ignorance of a topic or area. The culture believes it understands and does not recognize the limitations of the actual knowledge of the system, its environment, or its application.

Self-Defeating Prophecy

The self-defeating prophecy (i.e. by stating the hypothesis you induce a set of conditions that prevent the hypothesized outcome) is a strong, yet subtle, form of bias in system design and operations decisions. A simple example of this is the statement, "All colors being equal, I like blue." The hypothesis, "All colors being equal", is immediately defeated by the statement, "I like blue". Thus placing stronger consideration of blue over all other colors in mind and creating a bias towards the color stated. The systems engineer will need to recognize these subtleties in meetings and discussions and ensure that problem statements do not contain subjective statements that bias the solution.

The corollary of the source, the self-fulfilling prophecy, must also be guarded against. The self-fulfilling prophecy is complex in action. It involves declaring an option to be the best (or the worst) and interpreting all evidence as supporting the conclusion regardless of the outcome. This creates a bias in the design or operations team for or against a particular option without objectively considering all aspects of that or the other options. This can be a dangerous bias and can lead to system failures or other unexpected/undesirable results.

The normalization of deviance, (i.e., that the deviated results are expected) (Vaughan, 1996), is another similar construct where the abnormal performance becomes expected and then becomes the normal course of the system operation. This was cited as a factor in the Columbia accident. (CAIB, 2003) The systems engineer must guard against such normalization, keeping the uncertainties and sensitivities before the system design or operations team.

Summary

Sociology provides many functions that exist within the organization. Opportunity structures provide an opportunity for the disciplines to mature their ideas and resolve questions and unexpected responses prior to carrying these through the decision board process. The systems engineer provides for these in the organizational structure and information flow process through the formation of informal status meetings, task teams, working groups, communities of practice, etc. as appropriate for the organizational culture and specific system development. The systems engineer should ensure that the organization has specified all unknown areas (specification of ignorance) to ensure these are properly addressed. System terminology is important in communication and mathematics provides a means to translate various discipline concepts. Socially expectect durations are also important to be managed as part of the system schedules and plans.

There are many social cultures represented by each discipline group, the line organization, and the project organization. Ensuring these cultures work together and do not create barriers is an important aspect of systems engineering. Social ambivalence, anomie, and dysfunction should be actively addressed with line management and project management for the system.

Reconsideration paths are a key sociological mitigation for those within the organization which encounter a social ambivalence on a specific system decision or topic. These paths should not consist of participants in the development organizational culture but should be able to discern the sociological as well as the technical forces contributing to the perceived conflict in the system. This helps mitigate social responses that can lead to system design activities or decision moving outside the organizational structure or attempting to bypass certain decision making steps.

Avoiding unintended consequenses is a large aspect of system engineering, understanding the social basis for these consequences is critical to system success. Unrecognized ignorance, error, and biases all lead to unitended results for the system in develop or operation.

By understanding the social principles involved in discipline integration activities, the systems engineering gains a necessary understanding of organizational disruptions to information flow. These principles enable the systems engineer to recognize and address information flow patterns for the success of the system.

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James G. Andrews received his PhD in Psychology from the University of Tennessee, Knoxville, Tennessee (1977). Jim was Senior Consultant at The Stanford Associates, The Transition Management Group-Outplacement International, the JM Perry Corporation and Principle Consultant at Right Management. Jim was Vice President of Organization Development and Human Resources for Salestar telecommunications intelligence company, and Rusher, Loscavio, Lopresto a national retained executive search firm. Jim was Lieutenant Commander in the U.S. Navy serving at the Naval Regional Medical Center in Oakland, CA as staff psychologist. He was a Group leader at the Meyer Friedman Institute for Coronary Artery Disease and Type-A Behavior change. He is a past President of the American Association for Training and Development, Golden Gate Chapter, San Francisco, and a past Chair of the Northern California Human Resource Association. Jim currently leads the Organization and Leadership Development Office at Marshall Space Flight Center, NASA.

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