Complex System Governance Reference Model

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Abstract This chapter provides an in depth exploration of the reference model for complex system governance (CSG). The CSG reference model is explored as the set of interrelated functions and associated communication channels that must be performed for a system to remain viable (continue to exist). To provide this exploration, this chapter is focused on three primary objectives. First, the background for the CSG reference model is developed. This background places the CSG reference within the larger scope of the emerging CSG field. Following the introduction to the role of the reference for CSG field development, the conceptual foundations are examined. These foundations include management cybernetics, systems theory, and system governance. Included in the management cybernetics discussion are the 10 communication channels that are used in the CSG reference model. Second, the CSG reference model is developed. This development explores the nine meta-system functions that constitute CSG. Each function is examined for the primary role, responsibilities, and representative products from the function. The functions provide 'what' must be done to execute CSG for a complex system. Third, the future directions for further development of the CSG reference model are explored. The fit of the reference model within the larger scope and development of the CSG field is examined.

Keywords Complex system governance · Reference model · Management cybernetics

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1 Introduction

Complex system governance (CSG) is an emerging field in the earliest stages of development. The introduction of this field has been previously suggested in several different works, most recently, Keating et al. (2019). In this previous work, CSG was defined as "*Design, execution, and evolution of the metasystem functions necessary to provide control, communication, coordination, and integration of a complex system."(p. 6).* Without repetition of earlier work, at a high level, the following elements of the definition are elaborated as essential foundations for our present purposes:

1. ***Communication***—the flow and processing of information within and external to the system that provides for consistency in decisions, actions, and interpretations made with respect to the system.
2. ***Control***—invoking the minimal constraints necessary to ensure desirable levels of performance and maintenance of system trajectory, in the midst of internally or externally generated perturbations of the system.
3. ***Coordination***—providing for interactions (relationships) between constituent entities within the system and between the system and external entities such that unnecessary fluctuations are avoided.
4. ***Integration***—continuous maintenance of system unity as a dynamic balance between autonomy of constituent entities and the interdependence of entities necessary to invoke a coherent whole. This interdependence produces the system identity (uniqueness) that exists beyond the identities of the individual constituent entities.
5. ***Design***—purposeful and deliberate arrangement of the governance system consistent with the achievement of desirable performance outputs and outcomes.
6. ***Execution***—performance of the system design within the unique system context, subject to the emergent perturbations stemming from both dynamic interaction with the environment as well as internal elaborations within the system.
7. ***Evolution***—the change of the governance system in response to internal and external shifts. These shifts may be in response to new knowledge, environmental perturbations, internal system perturbations, or emergence.
8. ***Metasystem***—the set of interrelated higher level functions that provide for governance of a complex system.

However, as compelling as this definition might appear, it creates a necessary but not sufficient set of conditions to fully articulate and prepare for practice related to CSG. In the earlier Keating et al. [19] work, the need for a 'reference model,' coupled with a corresponding development framework, was identified as one of the critical elements for CSG field development. The other two elements included: (1) setting of a comprehensive research agenda to direct purposeful development of the field, and (2) introduction of an initial set of challenges to focus research around areas with the potential to address some of our most vexing problems in dealing with complex

Fig. 1 CSG reference model fits within the developing CSG field

systems. Thus, the need for a CSG reference model was identified as one of three critical elements in a triad for the development of the CSG field as first expounded in Keating et al. [19] and shown in Fig. 1.

The first element of the triad for development of the CSG field includes setting of a comprehensive research agenda to guide holistic field development in an integrated fashion. The research agenda serves to position current and ongoing research within the larger context of research and entities undertaking research related to the CSG field. It offers an organizing approach to accelerate development of the field with the ultimate objective of engaging coherent and rigorous research to improve practice. The second element of the triad involves generation of a CSG reference model and corresponding CSG development framework. The reference model establishes a conceptually grounded representation of a complex governance system from a theoretically, axiomatically, and axiologically consistent frame of reference. In addition, the corresponding CSG development framework provides a corresponding guide for the methodological, method, and application of CSG to successfully bridge knowledge to practice. In effect, the development framework serves to advance the CSG field while bringing it to the world of the practitioner, offering a comprehensive approach for the analysis and methodical development of governance for a complex system. The third and final element of the triad involves the introduction of an initial set of challenges, around which research can be undertaken to advance the CSG field and begin elaboration of the research agenda. The CSG reference model serves an important role in the developing CSG field and is a precursor to the development framework and an essential element of the research agenda.

To serve the primary purpose of expounding the CSG reference model, the chapter is organized to accomplish three primary objectives. First, we set the conceptual foundations for the CSG reference model. This foundation is based on Beer's [3, 4, 6] metasysem as described in the viable system model. In effect, the metasystem is stationed 'above' or 'beyond' the entities it serves to integrate, coordinate, and control [15, 19]. Therefore, the metasystem construct is ideally suited as a starting point from which to develop and ground CSG in the conceptual underpinnings of systems theory and management cybernetics. The second objective is focused on introducing the CSG reference model. The nine functions and subfunctions of the CSG reference model are developed with respect to their primary purpose and set of requirements that must be achieved in fulfilment of the function/subfunction. Third, we examine the future directions for further elaboration and development of the CSG reference model and the fit of this model within the larger development of the CSG field. As part of this examination, the role of the CSG reference model in relation to the other CSG field development areas is explored. The chapter concludes with a set of implications that the CSG reference model holds for the emerging field of CSG, along philosophical, theoretical, axiomatic, axiological, methodological, method, and application development challenges.

2 Conceptual Foundations for the CSG Reference Model

In setting the stage for the development of the CSG reference model, we focus on management cybernetics as a foundation upon which to build. Management cybernetics, or sometimes referred to as organizational cybernetics, was developed by Beer [3, 4, 6] in the form of the viable system model (VSM) and described by Beer as the 'science of effective organization'. In addition, we rely on systems theory as a philosophical, theoretical, and axiomatic basis for our development of the CSG reference model. In this section, we identify the two primary conceptual bases for our reference model development.

Systems theory provides a strong theoretical grounding for the CSG field as well as the constituent CSG reference model. Systems theory has been previously linked to the CSG field Keating et al. [19] and identified by Adams et al. [1] as a set of axioms and associated propositions (principles, concepts, and laws) that seek to describe the behavior of both natural and manmade systems. The concepts of systems, and the emergence of systems theory, are certainly not new. In fact, the foundations of systems thinking have been traced as far back as the ancient Chinese work *The I Ching*, translated as book of change and dated to be at least 5000 years old [23]. This work noted the dynamic nature of changing relationships among elements. Additionally, the central philosophical tenet of systems thinking, *holism*, can be traced back to the writings of Aristotle, who suggested that 'the whole is more than the sum of its parts'. In one of the most cogent presentations of systems theory, Adams et al. [1] have consolidated the body of systems theory knowledge around a set of organizing axioms and corresponding propositions (principles, concepts, and laws). For brevity, we have included Table 1 that specifies the systems theory axioms (following the work of Adams et al. [1]) and draws the implications for the current development of the CSG reference model. For an extended discussion on systems theory the reader is referred to the more complete work of Adams et al. [1] and for explication of the nature of systems theory to the CSG field the works of Keating et al.

Table 1 Systems theory axioms and governance

Systems theory axiom	Complex system governance reference model Implications
Centrality Axiom—central to all systems are emergence and hierarchy and communication and control	• Deal with emergent conditions and perturbations • Define relationships for accountability and responsibility • Information for consistent decision, action, and interpretation • Monitor and maintain performance while preserving maximum autonomy
Contextual axiom—meaning in systems is derived from the circumstances and factors that surround them	• Compatible with the context and environment within which the system exists • Flexibility based on shifting context • Articulates, monitors, interprets, and responds to context and contextual shifts
Goal axiom—systems achieve specific goals through purposeful behavior using pathways and means	• Establish, monitor, and maintain strategic direction and identity • System purpose, goals, and objectives consistency • Coherence in identity • Cohesive force that maintains integrity of the system in focus
Operational axiom—systems must be addressed in situ, where the system is exhibiting purposeful behavior	• Guide system strategic execution • Consistency in system behavior and performance • Production of outputs and outcomes consistent with expectations
Viability axiom—key parameters in a system must be controlled to ensure continued existence	• Measurement of system performance • Monitor and process internal and external fluctuations • Regulate key parameters essential to continued system existence
Design axiom—purposeful imbalance of resources and relationships	• Maintain and evaluate system model against execution • Model the present and future system • Establish exchange in system (matter, energy, information)
Information axiom—systems create, process, transfer, and modify information	• Information needs for decision, action, and interpretation support • Efficiency in exchanges • Dynamic information access, availability, or utility

[19] and Whitney et al provide a detailed development. As the CSG field becomes established, systems theory offers a strong theoretical foundation upon which to anchor the field, following the development of Adams et al. [1] and adapted from the earlier work of [18]. It is important to note that the axioms, as well as constituent propositions, do not operate independently or in mutual exclusivity of one another.

The contributions of systems theory to the emerging CSG reference model are summarized as: (1) grounding the model in a strong philosophical and theoretical basis, (2) reliance on a philosophic/theoretical foundation that has withstood the test of time, and (3) establishes a multidisciplinary foundation that supports model application across a spectrum of fields and applications.

The VSM serves as an excellent foundation for the development of the CSG reference model. The essence of the VSM [3, 4, 6] related to the development of the CSG reference model is held in two primary contributions. First, the VSM is concerned with the design for requisite variety [2], which basically states that the control in a system is a determined by the degree to which the regulator of a system is capable of matching the variety (complexity) being generated external to the system (from the environment). Hence, 'requisite' is the variety that must be generated to regulate and maintain system viability within established or desired limits. If external variety exceeds the variety (matching) capability of the regulator (providing feedback for system adjustment to maintain key parameters), then the system will not maintain viability (existence).

From this simple relationship, [3, 4, 6] expounded the VSM as a set of functions that provides for the disposition of system variety through *filtering* (attenuating variety by limiting variety beyond the capacity of the system to respond), *amplification* (generation of larger amounts of variety from the system to better match variety being externally cast upon the system) and *transduction* (translation to preserve meaning across system boundaries). This control, through the regulation of variety, is control in the cybernetic perspective, as opposed to more pejorative interpretations of control as domination of an individual or entity that limits independence. Consistent with a cybernetics perspective of control, control is neither a good nor bad, but rather an element that exists in every viable (existing) system. In this sense, management cybernetics embraces control as: (1) necessary to ensure a system continues to exist in response to environmental perturbations, (2) only provides a minimal set of constraints [regulation] on the system necessary and sufficient to maintain performance and behavior of the system, and (3) preserving autonomy [freedom and independence of decision, action, and interpretation [19, 20] of constituent entities in a system].

A second major contribution of management cybernetics is the identification of a set of interrelated metasystem functions in the VSM that provide for the continuing viability of a system. The metasystem provides the integration and coordination necessary to ensure that a system continues to produce the products or services that allow it to meet performance levels necessary to continue to operate (exist). Failure of any of the metasystem functions would jeopardize the overall system. Beer's formulation of the metasystem provides 5 essential functions for continued systemviability. For brevity, the metasystem functions of the VSM are provided

Table 2 Metasystem functions in the VSM

VSM Metasystem function	Role of the function
Coordination system 2	• Provides for system stability by preventing unnecessary fluctuations within the set of systems being integrated by the metasystem • Promotes operational system performance by ensuring sufficient integration within the system • Acts to harmonize the system such that the system acts in unison • Limits unnecessary turbulence, increasing system efficiency as well as effectiveness
Operational control system 3	• Maintains operational performance on a day to day basis • Provides for the execution of policy, distribution of resources, and accountability within the system • Focused on near term achievement and maintenance of system performance levels
Audit and accountability system 3*	• Provides monitoring of the system to identify aberrations and invoke necessary explorations to determine the source of the aberrant behavior or unexpected variance • Essential to understand the nature of variance and focus actions to resolve variance
Development system 4	• Scans and captures information from the environment and assesses that information for strategic implications and system level impacts • Models the future and strategic evolution of the system
Policy system 5	• Provides for the strategic decisions and direction that maintain the identity of the system • Monitors and maintains a balance between the inherent tension between the long-term external focus and the short-term internal focus of the system

(consistent with earlier summaries from [13, 19] to offer a high level overview of [3, 4, 6] VSM metasystem functions (Table 2).

The third major contribution of management cybernetics and the VSM is the inclusion of *communication channels*. Table 3 is provided as a summary of communication channels for the VSM based on several works articulating Beer's VSM [3–6, 9, 10, 13] as supplemented by [16].

The metasystem construct makes several important contributions to our conceptual foundations for the CSG reference model, including: (1) since the metasystem operates at a higher logical level beyond (meta) to the elements (entities) that it must integrate, we can focus on the integration, coordination, communication, and control at a level beyond the entities that are governed, (2) being that the metasystem has been conceptually grounded in the foundations of systems theory and management cybernetics, the conceptual lineage has been established and provides a more robust foundation, (3) the 'function' view of metasystem permits a focus on defining *what* must be achieved to fulfil the function, as opposed to *how* it must be fulfilled, (4) the metasystem functions are interrelated and do not operate in isolation from

Table 3 Communication channels in the VSM

Communicationchannel	Primary functions
Command	• Provides direction to operational units • Dissemination of non-negotiable direction to the system
Resource bargain/Accountability	• Provides/determines the resources (manpower, material, money, information, support) for operational units • Defines performance levels to which operational units will be held responsible • Determines how operational units will interface for performance reporting and accountability
Environmental Scanning	• Provides design for sensing of the external environment • Identifies environmental patterns, activities, or events with system implications • Provided for access throughout the metasystem as well as governed systems
Operations	• Provides for the routine interface between operational system entities and from the metasystem to operational units
Coordination	• Provides for system balance and stability by ensuring that information concerning decisions and actions necessary to prevent disturbances are shared among operational units
Audit	• Provides routine and sporadic feedback on the performance of system operations • Investigates and reports on problematic areas
Algedonic	• Provides instant alert to crisis or potentially catastrophic situations occurring in the system • Bypasses routine communications channels and structure to identify system threats
Dialog	• Provides examination and interpretation of organizational decisions, actions, and events • Seeks alignment of perspectives and shared understanding of organizational decisions and actions in light of system purpose and identity
System learning	• Provides detection and correction of system errors, testing of assumptions, and identification of system design deficiencies • Ensures that the system continually questions the adequacy of its design
Informing	• Provide routine transmission of information throughout the system • Routes information that is not appropriate for other channels for accessibility throughout the system

one another, in effect operating as a system in and of itself, (5) the performance of metasystem functions is necessary to produce continued viability, not necessarily high performance, as a system can exist at various levels of performance, and (6) by understanding the nature and role of the metasystem functions, functions can be purposefully designed, executed, and maintained.

The final element in the conceptual foundation for the CSG reference model is the CSG field. Since we have provided an essential development of the CSG field in the introduction to this chapter, we now shift to the development of the CSG reference model.

3 Complex System Governance Reference Model

The CSG reference model is proposed as a critical element in the development of the CSG field. The reference model provides a systemic representation of CSG, built upon the intellectual foundations of systems theory and management cybernetics. The purpose of the CSG reference model is to provide an organizing construct for the interrelated functions necessary to perform CSG. The CSG reference model is designed to provide the following contributions to the emerging CSG field:

- *Common Grounding Reference Point*—the model provides a common model for identification of 'what' a governing metasystem must accomplish if the system is to remain viable. Arguably, any complex system that exists is performing the functions of the CSG reference model, albeit they may be performed at a minimal level.
- *Set of Common Functions and Requirements*—the model provides a detailed explication of the functions that must be performed for governance of any complex system. This level of detail for governance, drawing back to the foundations of systems theory and management cybernetics, is essential to CSG field development.
- *Multiple Utility*—the model informs analysis, design, maintenance, and evaluation for CSG. As such, it provides both researchers and practitioners a valuable artifact for dealing with complex systems.
- *Foundation for Field Related Development*—the model provides a foundation for other developments and contributions to the CSG field, not limited to development methodologies, methods development, tools/software development, and research.

Prior to getting into details concerning the CSG reference model, we offer a high level depiction of the model. We have been careful to point out the consistencies, as well as elaborations, from the metasystem functions identified by Beer's early works [3, 4, 6]. With respect to the metasystem functions of the VSM, the CSG reference model has the following commonalities/distinctions: (1) the numbering convention has been kept consistent to avoid confusion between the VSM metasystem functions and the CSG metasystem functions, (2) the communication function has been directly incorporated into the CSG reference model to amplify the importance of communications with respect to the other functions, (3) the number of functions/subfunctions has been extended to nine to amplify additional functions we feel are necessary and sufficient for metasystem design, and (4) we have treated the productive system in Beer's VSM as a 'black box' in our CSG reference model, allowing the focus to be on the interrelationship of the metasystem to the entities being governed, not on the entities themselves. Our departure from the strict confines of Beer's VSM metasystem formulation (proposed over four decades ago) may be unsettling to purists. However, we have elaborated, modified, and extended the metasystem of the VSM to fit the purposes of CSG. This does not cast doubt or challenge the basis or formulation of the VSM. On the contrary, it simply evolves and extends the VSM to better fit our intended use for representation of CSG. There are nine metasystem functions that we have identified for our CSG reference model. A brief depiction of the nature and role of the metasystem functions is:

- *Metasystem five (M5)—Policy and identity*—corresponds to system 5 in the VSM metasystem, focused on overall steering, giving direction and identity for the system
- *Metasystem five star (M5*)—System context*—elaborates a responsibility within the VSM system 5, focused on the specific context within which the metasystem is embedded
- *Metasystem five prime (M5')—Strategic system—monitoring* elaborates a responsibility within the VSM system 5, focused on oversight of the system at a strategic level
- *Metasystem four (M4)—System development*—corresponds to system 4 in the VSM metasystem, focusing on the long range development of the system to ensure future viability
- *Metasystem four star (M4*)—Learning and transformation*—elaborates a responsibility within the VSM system 4, focused on facilitation of learning based on correction of design errors in the metasystem and planning for transformation of the metasystem.
- *Metasystem four prime (M4')—Environmental Scanning*—elaborates a responsibility within the VSM system 4, focused on sensing the environment for trends, patterns, or events with implications for both present and future system performance and development
- *Metasystem three (M3)—System operations*—corresponds to system 3 in the VSM metasystem, focused on the day to day operations of the metasystem to ensure that the system maintains performance levels.
- *Metasystem three star (M3*)—Operational performance*—corresponds to system 3* in the VSM, focused on monitoring system performance to identify and assess aberrant conditions.
- *Metasystem two (M2)—Information and communications*—elaborates the system 2 function in the VSM to focus on the design for flow of information and consistent interpretation of exchanges (communication channels).

The detailed articulation of these metasystem functions is depicted in Table 4. As shown in Fig. 2, the functions are interrelated. None of the functions operates independent of the other functions. In addition, it is important to note that none of the functions is 'more important' than the others. Consistent with the VSM, all of the CSG reference model functions are necessary to ensure the continuing viability of the entire system. Poor performance of one metasystem function will propagate through the entire metasystem. The metasystem functions are performed through associated

Table 4 Metasystem functions for the CSG Reference Model

Metasystem function	Primary role	Responsibilities	Products
Metasystem five (M5)policy and identity	Primary function is to provide direction, oversight, accountability, and evolution of the system. Focus includes policy, mission, vision, strategic direction, performance, and accountability for the system such that: (1) the system maintains viability, (2) identity is preserved, and (3) the system is effectively projected both internally and externally	• Establishes and maintains system identity in the face of changing environment and context • Defines, clarifies and propagates the system vision, strategic direction, purpose, mission, and interpretation • Active determination and balance for system focus between present and future • Disseminates strategic plan and oversees execution • Provides for capital resources necessary to support system • Sets present and future problem space for focus of product, service, and content development and deployment • Sets strategic dialog forums • Preserves autonomy and integration system • Marketing of system products, services, content, and value • Public relations planning and execution • External mentorship development (e.g., Board of directors) • Establishes system policy direction and maintains identity of the system executed through strategic direction • Represents the system interests to external constituents • Defines and integrates the expanded network for the system (strategic partnerships) • Evolves scenarios for system transformation and implements strategic transformation direction	• Forums and mechanisms to define, maintain, and evolve system identity and focus (mission, vision, strategic direction, purpose) • Strategic system plan • Public relations plan execution and performance monitoring • Marketing plan execution and performance monitoring • Integrated system mapping • Satisficing system policies • Governance architecture for the metasystem

(continued)

Table 4 (continued)

Metasystem function	Primary role	Responsibilities	Products
Metasystem five star (M5*)system context	Primary function is to monitor the system context (the circumstances, factors, conditions, or patterns that enable and constrain the system)	• Identify system context and provide for assessment of contextual impacts on system performance (constraining or enabling) • Actively manages context • Conducts boundary spanning to determine the boundary conditions, values, and judgments for the system • Conducts inquiry into contextual barriers to system execution or development • Monitors and assesses the influence of contextual aspects for the system • Informs development of the strategic plan	• Stakeholder analysis • Contextual mapping • Contextual monitoring and development strategy
Metasystem five prime (M5')strategic system monitoring	Primary function is to monitor measures for strategic system performance and identify variance requiring metasystem level response. Particular emphasis is on variability that may impact future system viability.	• Track ongoing performance of system based on measures of performance for operations • Disseminates system performance throughout system • Identification, analysis, and maintenance of system context • Conducts inquiry into performance aberrations • Monitors and assesses the continuing adequacy of strategic system performance measures • Informs development of the strategic plan	• Measures for strategic system performance • Results of inquiry and analysis of performance issues • Recommendations for continuance, modification, or deletion of performance measures
Metasystem four (M4)system development	Primary function is to provide for the analysis and interpretation of the implications and potential impacts of trends, patterns, and precipitating events in the environment. Develops future scenarios, design alternatives, and future focused planning to position the system for future viability	• Analyzes and interprets environmental scanning results for shifts, their implications, and potential impacts on system evolution • Guides development of the system strategic plan and system development map • Informs the development of the strategic plan • Guides future product, service, and content development • Guides investment priorities • Identifies future relationships critical to system development • Identifies future development opportunities and targets that can be pursued in support of mission and vision of the system	• Planning for response to environmental scanning • Models of the present, future, and environment for the System • Strategic system development plan and system development map

(continued)

Table 4 (continued)

Metasystem function	Primary role	Responsibilities	Products
Metasystem four star (M4*)learning and transformation	Primary function is to provide for identification and analysis of metasystem design errors (second order learning) and suggest design modifications and transformation planning for the system	• Processes inputs for system wide implications • Identifies mechanisms for double loop Learning • Designs objectives, measures, and accountability for second order learning in the system • Leads in future transformation analysis • Provides future focused input to strategy development • Informs the development of the strategic plan	• Design for second order system learning • System transformation strategy • Dissemination of learning results, implications, and opportunities
Metasystem four prime (M4')environmental scanning	Primary function is to provide the design and execution of scanning for the system environment. Focus is on patterns, trends, threats, events, and opportunities for the system	• Designs for environmental scanning for the entire system (includes trends, changes, patterns, critical stakeholders, collaborative entities, research, etc.) • Executes the environmental scanning design • Maintains a model of the metasystem environment • Captures emergent environmental conditions and events • Consolidates results from environmental scanning and provides synthesis • Informs the development of the strategic plan • Disseminates essential environmental information and shifts throughout the system	• Design for environmental scanning including objectives, organization, execution, and performance monitoring • Publication of environmental scanning activities enabling coordination of targets, execution, data capture and analysis • Dissemination of scanning results, and implications of patterns, trends, threats, events, and opportunities for the system

(continued)

Table 4 (continued)

Metasystem function	Primary role	Responsibilities	Products
Metasystem three (M3)system operations	Primary function is to maintain operational performance control through the implementation of policy, resource allocation, and design for accountability	• Oversight for products, services, value, and content delivery • System planning and control for ongoing day to day operational effectiveness • Develop near term system design response to evolving operational issues and monitor operational performance measures • Operationally interprets and ensures implementation of the system policies and direction • Interpretation and translation of implications of environmental shifts for operations (based on inputs from system development) • Informs the development of the strategic plan • Determines resources, expectations, and performance measurement for operational performance • Design for accountability and performance reporting for operations	• Operational plan for production of system that generates value • Execution forums for ongoing operational maintenance • Resource planning for operational requirements • Establishes operational goals in relationship to strategic performance objectives • Sets priorities and resource allocation for operational support activities and investments • Determines performance measure targets
Metasystem three star (M3*)operational performance	Primary function is to monitor measures for operational performance and identify variance in system performance requiring system level response. Particular emphasis is on variability and performance trends that may impact system viability	• Track ongoing performance of system based on measures of performance for operations • Disseminates system performance throughout system • Conducts inquiry into performance aberrations • Informs the development of the strategic plan • Monitors and assesses the continuing adequacy of operational performance measures	• Measures for operations • Results of inquiry and analysis of performance issues • Recommendations for continuance, modification, or deletion of performance measures

(continued)

Table 4 (continued)

Metasystem function	Primary role	Responsibilities	Products
Metasystem two (M2)information and communications	Enables system stability by designing and implementing the architecture for information flow, coordination, transduction and communications within the metasystem and between the metasystem, the environment and the governed system	• Designs and maintains the architecture of information flows and communications within the metasystem, between the metasystem and environment, and between the metasystem and the governed system • Ensures efficiency by coordinating information accessibility within the system • Identifies standard processes and procedures necessary to facilitate transduction and provide effective integration and coordination of the system • Informs the development of the strategic plan • Identifies and provides forums to identify and resolve emergent conflict and coordination issues within the system	• Standard processes and procedures for internal coordination of the system • Communications architecture for the metasystem • Defined external coordination vehicles necessary for support for the system (e.g., public relations, press releases)

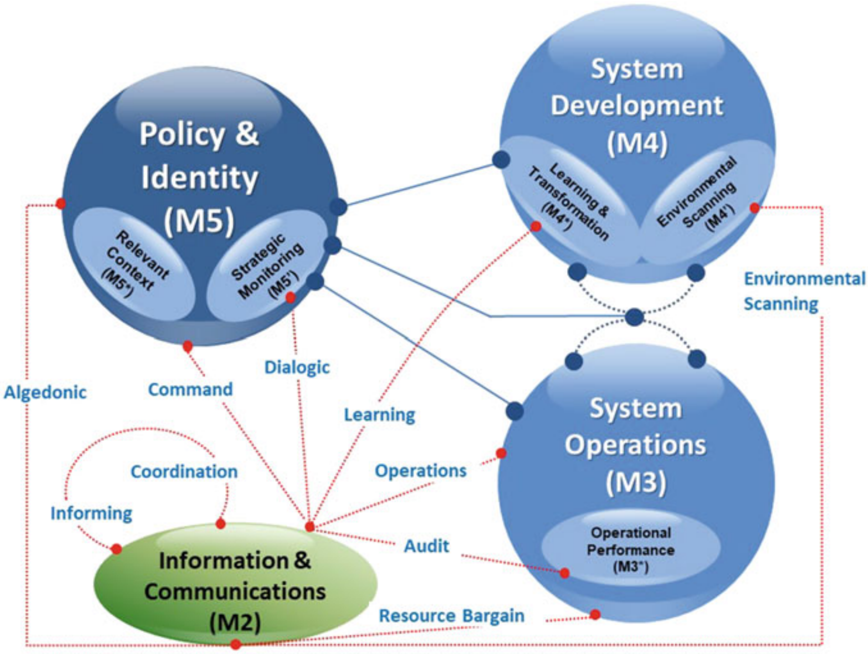

Fig. 2 CSG Reference Model interrelated functions and communications channels

mechanisms (the particular implementing devices that execute the metasystem function and exist in relationship with other mechanisms within the metasystem). The set of mechanisms and their interrelationships provide the structure that permits performance of the metasystem functions.

4 Conclusions and Implications

This chapter represents a refined development of a reference model suitable for the emerging field of CSG. We consider this model to be continually evolving, although it is thoroughly grounded in systems theory and management cybernetics. However, the complexity of the ideas and underlying theoretical foundations suggest that the model will naturally evolve as we gain experience that only time, and applications of the model can bring. The CSG reference model represents an important step forward for the CSG field. The reference model provides a foundation upon which there can be an evolution of development frameworks, corresponding methods to support application, software-based tools, and the underpinnings for applications based on deployment of the model. In addition, the model provides opportunities to make further contributions to the body of knowledge through research undertaken to further explore, test, and evaluate efficacy of the model. In effect, the building of the CSG

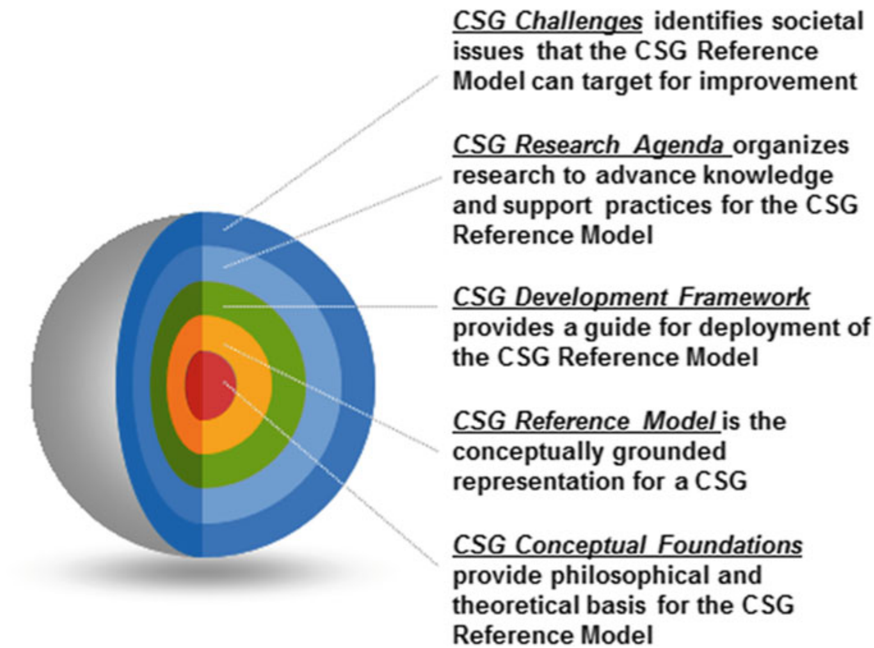

Fig. 3 CSG Reference model as an element in building the CSG field

reference model represents a necessary response to establishing a grounding frame of reference, based on the strong philosophical and theoretical linkage to systems theory and management cybernetics. Figure 3 captures the CSG reference model within the larger developing field of CSG. In effect, the CSG reference model: (1) is built upon a sound theoretical base (systems theory and management cybernetics), (2) provides an important element in the emerging CSG frameworks to guide application, (3) serves to inform critical developmental areas for research endeavors in CSG, and (4) supports meeting the application challenges that modern complex systems pose.

The current state of CSG reference model development provides two important contributions directly related to moving the CSG field forward. First, the reference model lies between the theoretical/philosophical roots of the field and the practical applications that can be built to deploy the model. As such, the model lies between the philosophical, theoretical, axiomatic, and axiological aspects of the CSG field development and the method, methodology, and application aspects of the field. The CSG reference model is a necessary development of the field to provide a bridge between the research-based and practice-based field development emphases. Second, the model supports a dialog important to the field. Continuing research articulates a sound systems theoretic grounded representation for CSG. Prior to this model, we have found little rigorously and theoretically grounded development of complex system governance. Existing models of governance Keating et al. [19] fall short on detailed development of the meaning, nature, and role that is played in CSG. The specific fit of the CSG reference model as an essential aspect of building the larger CSG field is suggested in Fig. 3.

In charting a course for further development of the CSG reference model there are several opportunities to accelerate growth of the CSG field. First, the model exists as a well-grounded representation of *what* must be achieved to fulfil the requirements for governance. However, the model should evolve as new and more rigorously developed explorations unfold. For example, the initial development of systems theory centerd around a formulation of 7 axioms and 30 corresponding propositions. While this was initially robust, care must be taken not to exclude a wider array of systems theoretic knowledge and what that formulation might bring to enhance further development of the CSG reference model and corresponding knowledge base. Second, the model should directly inform approaches to engage CSG development. The generation of a development framework(s) for CSG is essential to build the field. The CSG reference model is an ideal candidate against which rigorous CSG development frameworks can be established.

Finally, there should be concentration in preparing for application of CSG through methods and applications supportive of both the CSG reference model and a corresponding development framework. In addition, there are opportunities to widen the grasp of the CSG field by inclusion of several related fields. For example, system of systems engineering [14, 17, 18] is a field with many parallels and strong linkage to CSG. We should avoid closing off the CSG field to other related fields. The premature closing of the CSG field, while possibly temporarily pleasing, may serve to overly narrow the field early and potentially preclude insightful lines of inquiry that could broaden the utility of the CSG field.

One such framework for application of the CSG reference model is the CSG architecture framework [7, 21]. This framework describes the conventions, principles and practices for establishing complex system governance architectures. This lies in support of accomplishing the 9 governance functions, 65 related responsibilities, and 34 related outcomes suggested for CSG. The framework also integrates 30 systems theory propositions [22] as well as metasystem pathologies encapsulating 83 systems theory-based pathologies stemming from Katina [11]. The CSG architecture exist as a first attempt to operationalize the CSG reference model in a form that is 'actionable'. CSG architecture development is targeted to three primary stakeholders [7]. Among these stakeholders are included:

- ***Complex System Owner*** is a person or organizational body responsible for maintaining system viability through decision making not delegated to a metasystem governor or metasystem governance function owner.
- ***Metasystem Governor*** is a person or organizational body responsible for maintaining system viability through accomplishment of all metasystem governance functions.
- ***Metasystem Governance Function Owner*** is a person or organizational body responsible for accomplishment of one or more metasystem governance function(s).

The CSG architecture framework is considered to be a dynamic toolset for complex system owners, metasystem governors, and metasystem governance function owners. The thrust of the toolset is focused on the discovery, development, and maintenance of information necessary for development of complex system governance architecture products (model-centric outcomes/representations). These products facilitate greater understanding of a system of interest performance of complex system governance functions. The CSG architecture framework is representative of efforts to advance the CSG field through making the CSG reference model actionable. In effect, the CSG architecture framework serves as a catalyst for transition from theoretical underpinnings of CSG, and the CSG reference model, to real world application of CSG and performance of metasystem governance functions and discovery of associated pathologies. These advances are critical to the continuing maturation of the CSG field through operational applications.

In closing, we are confident that this foray into the CSG reference model has contributed to pushing the CSG field forward. CSG reference model-based applications, such as the CSG architecture framework, represent a vital step forward in depicting the functional elements of governance, their execution, and their interrelationships.

5 Exercises

1. Describe the role of the CSG reference model for the CSG field.
2. Identify a system of interest (SoI). For the SoI identify at least one mechanism (a vehicle used to implement a function) for each of the nine metasystem functions (e.g., weekly staff meeting for Operations function).
3. For a system of interest (SoI), for each of the 10 communication channels select at least one mechanism (vehicle used to fulfil the communication channel) for each of the channels (e.g., daily newsletter for Informing Channel).

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