A SE VSE Company Use Case

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Abstract. Prime Solutions Group, Incorporated (PSG) is a systems engineering company and Very Small Entity that has benefited from association with INCOSE and specifically the Very Small Entity Working Group. This paper presents the company's use of the INCOSE Very Small Entity Working Group Deployment Packages for research projects, engineering services and software development. Further tailoring of the Very Small Entity Working Group Deployment Packages derived from ISO/IEC Technical Report 29110 into a System of Research & Development Innovation is discussed. Finally, the current INCOSE Technical Operations policy review and update activity is presented as an example of applying Very Small Entity systems engineering process on INCOSE. The objective of the paper is to describe the application of an INCOSE technical product in the small business world.

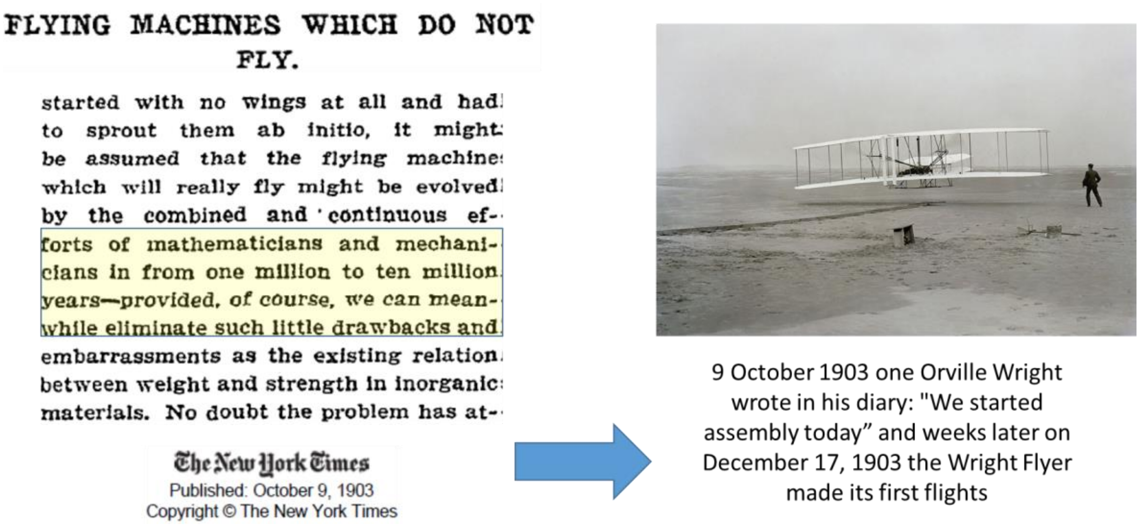
Introduction

PSG is a systems engineering Small and Medium Enterprise (SME) and a Very Small Entity (VSE). In our case, we are a small company of 20 people. Process, structure, and approaches are important to us because it represents how we do business accomplish success on projects and demonstrate our competency for current and our next customer(s). Indeed, every small and large business as well as associations such as INCOSE needs to address process or face frustration or perhaps extinction. In this paper, we talk about our specific use case as a VSE and the types of processes we have developed and explored. Included is a description of a related process and policy review in our very own INCOSE.

Participation in the INCOSE VSE WG has direct application to PSG's mission and focus and elevates our confidence as a VSE in pursuit of business opportunities in systems engineering. In the U.S.A., VSEs have been responsible for creating many innovations through non-diluted funding of the Small Business Innovative Research/Scientific Technology Transfer (SBIR/STTR) programs. The success stories are many and include innovative products and organizations which got their start as SBIR/STTR projects. These include Google and GoreTex. Our interests are in innovative research that help solve complex defense systems through systems and software engineering research. Early in our lifecycle, we had to come to grips with that as our mission statement and be careful to codify that in a way that people who don't understand SE can understand what we do and what value we can bring to potential customers.

The contributions of small business in the global economy are well documented. The Organisation for Economic Co-operation and Development (OECD) reports on the value of Small and Medium Enterprises (SMEs) which comprise over 95% of all enterprises and accounts for two thirds of private sector employment around the globe. (OEDC, 2005) Small businesses not only accounts for a large percentage of the global economy, they have the primary source of innovation and new ideas. For example, the Wright Brothers never gave up on their quest to build a flying machine while many others had dismissed the idea. Figure 1 shows the article published in 1903 by the New York Times in an editorial that declared we were from one million to 10 million years away from a flying machine. On December 17, 1903 — about nine weeks after the Times' editorial — Orville and Wilbur Wright took to Kitty Hawk, North Carolina, with their plane, the Wright Flyer. They successfully took to the skies four times that day, including a flight over 800 feet lasting nearly a full minute. (English, 2016) The VSE company of two brothers changed the 20th century.

Small business VSE are well-served to consider the value of process implementation to invigorate growth. In our experience, DPs are necessary but not sufficient to maintain the business structure and hence profitability. Our proposition is simple: the successful VSE looks at the business as a system and develops a framework for process development and maturity.



FLYING MACHINES WHICH DO NOT FLY.

started with no wings at all and had to sprout them ab initio, it might be assumed that the flying machine which will really fly might be evolved by the combined and continuous efforts of mathematicians and mechanicians in from one million to ten million years—provided, of course, we can meanwhile eliminate such little drawbacks and embarrassments as the existing relation between weight and strength in inorganic materials. No doubt the problem has at-

The New York Times
Published: October 9, 1903
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Figure 1. A VSE Changed the World

VSE WG DPs

DPs are a guide and introductory steps consistent with the ISO/IEC Technical Report 29110 derived from ISO/IEC 15288, the Systems and software engineering standard. As VSEs, it is incumbent upon us to take responsibility for tailoring any standard for our particular situation. This includes ISO/IEC 29110 as well as ISO/IEC 15288. Any other approach would be irresponsible and indicative of a VSE that is going out of business.

Table 1 below provides a general summary of DP applications in both internal company uses and customer uses. In the table, Observation refers to our internal perspective of each DP. Customer uses refers to DP use on direct contract work.

The sub-sections following Table 1 provide specific use case descriptions where application of DPs has impacted the company bottom line in both internal and external facing activities.

Table 1. DPs Apply to Internal and External facing activities

VSE WG DP	Observation	Customer Uses
Program Management	Program Management DP used routinely to set up and manage internal business and research projects. Important both internally and externally to customers who need to understand management processes	Program Management DP used to describe the Program Management functions in multiple proposals responsible for over $5M in contract work over the past 3 years
Requirements Engineering	Develop company enterprise architecture requirements that drive migration from today's 'as is' to tomorrow's 'to be' architecture. A fundamental aspect of everything we do	Requirements management is an expected functional capability in PSG's supply chain. Inability to track and manage requirements is a significant deficiency
Functional & Physical Architecture	Essential to architecting not only the business model, but also important to the IT architecture that allows product development	Customers recognize the value and maturity level offered in a discussion about architecture and ways to create a living architecture throughout the lifecycle

Configuration Management	Configuration management of hardware, software and data resources saves money on re-work and time locating current configurations	Mandated through contract requirements and workflow responsibilities
Interface Management	A critical function for managing functionality and Intellectual Property rights Interface management has been most important on internal R&D	Most engineering service contract activities perform interface management at higher levels on the supply chain
Integration	Key component to research especially in open source software integrations that perform complex functions	Integration process is critical to product development and software delivery on service contracts
Verification & Validation	V&V at individual developer levels in agile development and also at sub component and products levels	Engineering services offering which is typically driven by customer requirements
Product Deployment	The most difficult task in product development, launch and commercialization	Engineering services offering which is typically driven by customer requirements
Self-Assessment	Continuous activity required to remain profitable among competitors	Assurance to customers and stakeholders the organization thinks through assessment

Research Projects. Our research interest is on systems topics where the objective is to understand uncertainty through modeling and simulation, Big Data Analytics or new tools and techniques for managing, modeling and simulation system complexity throughout the lifecycle. The research projects require concise, complete and achievable task descriptions. To accomplish this we must be able to organize tasks in logical sequences, show their interrelationships and describe how the results of each task feed future tasks. VSE WG DPs are ideal aids and checklists for rapid spin up of a research project.

SBIRs require a simplified approach to program management and systems engineering since they are relatively short term and results oriented. Program management and systems engineering are needed to organize and manage the project, but should not be time consuming or restrictive on performance of innovative research. Toward that end, PSG has further tailored the VSE WG DPs to provide a repeatable process for developing an SBIR proposal and implementing the project if it is selected for award. Table 2 below is a summary of the DP and the tailored application which address elements expected by SBIR sponsors.

Table 2. Tailored DP Approach to Research Proposals

VSE WG DP	SBIR Tailored Application
Program Management	Tailored MilStd 881 work breakdown structure (WBS) that includes Program Management. This WBS provides a template for developing the overall research approach. Develop a summary schedule and assign resources to develop project responsibilities, task allocations and costs
Requirements Engineering	Collect requirements from topic description and establish these as a baseline among the project team
Functional and Physical Architecture	Create simple Systems Modeling Language (SysML) Use Case Diagrams and Block Definition Diagrams. These can typically be used to illustrate the approach and communicate understanding of the problem significance
Configuration Management	Configuration Management of project software, development environment, data and technical feasibility end items is easily described and important to sponsors to understand what is being done and how it will be managed
Interface Management	Interface Management and Integration are combined into an agile systems and software engineering process where the team performs a daily standup meeting and a more involved bi-weekly planning meeting to conduct a more detailed plan of short term tasks
Integration	
Verification Validation	These research projects do not typically have a formal V&V process, but allocation of specific requirements to continuous engineering and testing directly describes the process for achieving results
Product Deployment	SBIR projects are at the technical feasibility and prototype stages, but thinking through an eventual Product Deployment strategy informs a commercialization approach which is a required component for these research projects
Self-Assessment	A continuous process both during the project approach development and incorporation of feedback if the project is not accepted for award

The tailoring of DPs described in the above table is continuously reviewed by our team on a project by project basis. The value to us as a VSE is that we have a starting point on each proposal and project. Sometimes the hardest thing to do is to get started and going to step one provides a template for kicking off ideas about complex research projects. This approach also provides a checklist for addressing project components that can make a difference on selection or non-selection of the proposal for funding.

Engineering Services. As compared to development and execution of internal projects leading to product development, engineering services provide direct support to customers. For PSG, this typically means providing systems and software engineers to perform work against specific tasks or statement of work. This work is managed by customer processes that deliver results to their customers.

Our use case with engineering services is aligned with a key tenet of VSE DPs. DPs suggest key tasks and activities consistent with the larger systems and software engineering standard in ISO/IEC 15288. They are not prescriptive, but suggest activities that a VSE should consider at increasing levels of maturity. Maturity levels are accommodated in the VSE DPs and provide a powerful tool to guide the VSE in determining their individual levels of maturing. These levels include a progression from Entry to Advanced over 4 incremental steps. This allows a VSE to enter and mature over time. See INCOSE VSE WG reference materials for more information.

This section explains how we have evolved VSE WG DPs into company processes, policies and procedures that help us manage our business and successfully execute on contract work. PSG uses Standard Operating Procedures (SOP) to capture business practices so they are documented and can be executed as repeatable processes. Table 3 is a list of the PSG SOPs. Our first SOP describes the process and implements a Process Review Board (PRB) that governs how we manage and update existing processes as well as add new processes that are necessary to manage the company.

Table 3. PSG Standard Operating Procedures

SOP Title	Description
SOP Management & Process Review Board	Describes the review, approval, and revision change methods for all PSG Policies and SOPs
Configuration Control Board (CCB)	Defines the responsibilities of the CCB including decision-making, authority for review, approval and control of cost and schedule baselines.
Review & Control Boards	Defines the administrative tasks of review and control boards conducted by each program and function within PSG.
SOP Origination and Modification	Establishes the SOP format as well as, the procedure for creating and modifying a SOP. It also provides a review schedule for the SOPs to ensure they remain current and relevant.
Document Standardization	Establishes guidelines for standardizing the preparation and control of documentation produced by PSG and ensuring each

SOP Title	Description
	documents contain the necessary components for compliance.
Action Items (AI)	Defines the process and responsibilities for conducting AI assignment, tracking and management using a variety of tools.
Directory Structure	Standardizes, describes, and regulates the PSG directory structure across the enterprise and program level filesystems.
Labor Charging Process	Defines direct and indirect labor-charging practices and processes. Time entries are the source documentation required by law for payroll and accurate recording, allocation and billing of labor charges to Government contracts

PSG also has policies that cover other relevant areas such as Code of Ethics, Confidentiality Agreements, Email Policy, Employee Handbook, Travel, Contract Charging, VPN Access, Property Management and Time Keeping.

Engineering Services – Meeting Supply Chain Requirements

As a VSE in the systems and software engineering supply chain, we are continually looking for new business, new teaming relationships and opportunities. As we have developed relationships with larger prime contractors, we have found that once discussions get serious about providing engineering support, the supply chain is energized. This leads to audits of the business for financial stability and process awareness. Larger companies need to know you have a sufficient level of maturity to meet process compliance above them in their supply chain.

Below is a list of processes we have been asked to present and qualify as a prerequisite for subcontracting to a major defense industry supplier. This is representative of the requirements levied by most prime contractors. We present it here and point out the intersection with many of the VSE WG DP topics. To answer these due diligence process audits, we have leveraged details presented in the DPs and incorporated that content into our SOPs discussed above. We have also found that it isn't the details prime contractors are interested in. They are most interested in the fact that you have considered these functional areas and have some process information in place and written down.

Supplier Due Diligence Plan

VSEs should also be aware that prime contractors in the supply chain want to see evidence that these processes exist and may request them as attachments in proposals and contracts. Again, they are not interested in the details. They want to know you have something in place to address the function which can be modified as necessary to meet specific contractual or programmatic needs. We suggest that VSEs develop similar processes and keep them handy in a notebook, because you will be asked for it. These are typical processes and include topics such as: 1) Change Management; 2) Configuration Control; 3) Design Review Process; 4) Retention of Quality Records; and 5) Safety.

System of R&D Innovation

This section describes how PSG strives to achieve excellence as an innovation company. Every step builds on previous work in developing process maturity and there are no shortcuts. In our case, this started with focus on VSE WG DPs to guide our early development and growth as a VSE. We used this foundation to branch out into development of our own functional processes which led to the ability to address customer supply chain functional process requirements as a prerequisite to subcontracting opportunities.

With the pedigree established through the progression described in this paper, PSG has been able to expand into a development process we call our System of R&D Innovation. We were motivated to move in this direction by one of the plenary speakers, Jan Bosch, at INCOSE IS 2015 in Seattle, WA. Figure 2 was a slide presented at the conference.

Figure 2. Stairway to Heaven

In order to have repeatable success with our R&D projects, we'll need to adhere to a process. This process can and should be flexible, intuitive, and responsive. That is, it needs to be mold-able to the issues at hand (flexible), easy to understand, implement, and use (intuitive), and finally quick to adapt to current needs (responsive).

Though R&D activities differ, a large portion of their steps or phases remain the same, at least at a high level. The following is a cut at these phases:

1. Identification
2. Refinement
3. Proposal
4. Research & Development
5. Retrospective

The below sub-sections describe the processes, tools and rationale for conducting each of these phases in a R&D activity. An important point is that many of these phases have a pedigree in VSE WG DPs.

Identification. Identification encompasses the steps involved in finding topics worth researching. This includes SBIR/STTR research, as well as independent selection of research topics. We can use this phase of the process to branch out and identify areas where we may be able to break into. Anyone can suggest a topic, but they must represent it in an "identification meeting". In the identification meeting, topics will be brought to the team where we can decide if it is "in our ballpark". We still want to use some restraint to keep to topics that we can at least remotely perform against. The next phase will help break down topics further.

Refinement. Refinement is where we "burn away" the topics that just aren't going to happen, or aren't near enough to our expertise for us to pursue with excellence. Each topic that makes it through, though, will go through this refinement phase and come out the other side more clear. We'll have a question session that helps identify areas of the topic that we are experts in as well as areas of necessary research. (Some "go-to" questions should be included as part of this process). Some basic research will also occur in this phase.

Proposal. During the proposal phase, we will either be writing a proposal to a requesting agency, or we will be writing up development plans for internal research (which should be easily convertible to proposals should the opportunity arise).

Research & Development. This will need to have a whole document to itself, but to start, development will need to occur in a repeatable, and tracked environment. We already use Atlassian products, so for project and ticket tracking, that's a good start. We use Git for code tracking, and decide on an integration management tool appropriate for the project (bamboo, Jenkins, etc.).

Retrospective. This phase will need to occur, in part, all along the process. We need to identify what is going and has gone right or wrong. This plays into the responsiveness and flexibility of our process. At set times, such as during write-up periods, we need to have a short meeting about how things are going and how they can be improved. At the same time, if there is something actively hindering the process, we shouldn't wait for this meeting to occur.

At the Core. Following the above R&D phases iteratively, tactical level tools and techniques have emerged that advance our ability to perform innovative R&D. PSG has developed a technique that extends current systems engineering and software development into a new construct that we call Model-Simulation-Analysis-Looping, or MSAL. The beauty of MSAL is that it can be applied at all levels of system engineering, systems modeling, software development, and testing. From the macroscopic to the smallest architectural elements, MSAL can be used to test model performance using data analytics or to iterate on the model development itself.

MSAL consists of four integrated components as follows, starting at the bottom left of the blue border in Figure 3. The block arrows are the looping between components. The terminology and architectural components of MSAL are defined in Table 4.

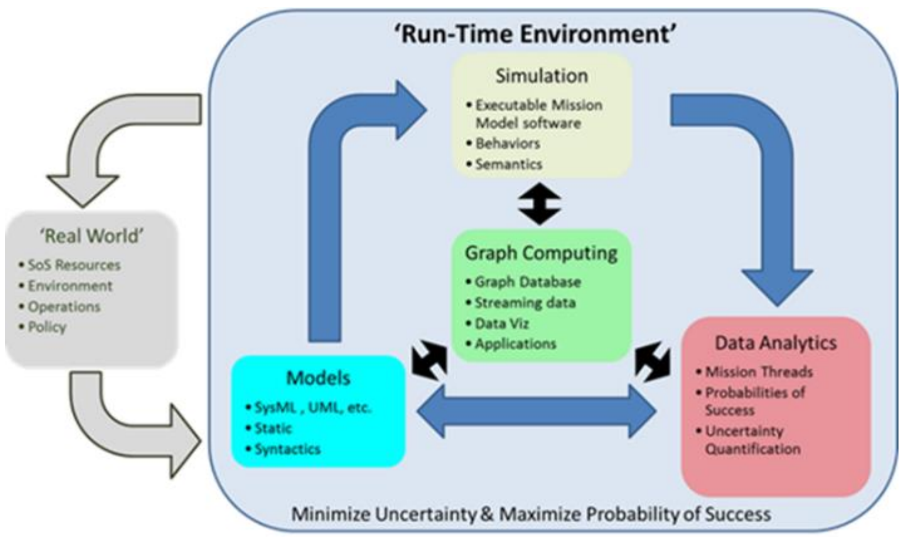

Figure 3. Models, Simulation, Data Analytics, and Graph Computing

By codifying and exercising MSAL, we have benefited from several observations and lessons learned that enhance our skills. Among these benefits is the realization that ontology is a critical element of any complex project. Table 4 below provides the reference terms we use with MSAL as an example. Each project must start with these terms and expand on appropriate definitions to ensure all stakeholders are using common terminology.

Table 4. MSAL Terminology and Architectural Components

Term	Description
Model	A static representation of the system entities (objects), their structure, and their interconnections. Models are represented as networks, or as nodes and edges in a graph database, and can capture and represent complex relationships in the system. The model represents the system's structure.
Modeling	The act of creating the static representation of system entities through software development and/or binding pre-existing models into a new system representation (i.e. a System of Systems).
Simulation	The act of executing the model with a given set of input parameters. Simulations are dynamic, time-domain representations of the model that include entity and inter-entity behaviors. They have quantitative behaviors and a simulation infrastructure, e.g., time management, data management, an optimizer interface, and data output schemes.
Simulation Engine	Drives model executions by generating unique parameter sets for each model execution. Through the simulation engine, one-at-a-time parameter studies can be executed to explore a parameter's effect on model output, or groups of parameters can be created for multiple parameter studies. Similarly, interesting parameters, or those which seemingly have the most impact on model output, can be the subjects of optimization campaigns. The simulation engine and model couplet becomes a "test harness" by which software components or software systems can be rapidly tested and analyzed. This enables the Model-Simulation-Analysis-Looping (MSAL) capability.
Data Analytics	Software that is used to address the large amounts of data produced by many iterative simulation runs and evolving models. Due to their superior performance in Big Data domains, graph databases have been incorporated as the foundation for MSAL's analytics capabilities.
Mission Environment (ME)	An ontology composed of an object-oriented, class structure of the operational mission goals, stakeholder requirements, resource entities, operations doctrine, and constraining policy. The mission environment represents the system context—the set of physical entities, conditions, circumstances, and influences needed to meet a specific mission goal. The mission environment provides the reality against which model performance can be evaluated.
Mission Goal	An explicit success criterion. Drawn from the mission environment, mission goals can be mathematically expressed as an objective function or functions for the purpose of optimization.

Term	Description
Mission Thread	Provides the operational and technical description of the end-to-end set of activities to meet a specific mission goal. The output from a simulation run is an instance of a mission thread. The compilation of the mission threads, or simulation outputs, bounds the model performance, providing a rich data set for subsequent analytics and performance evaluation.

MSAL facilitates multiple iterations between modeling, simulation, and data analytics, allowing one to more quickly observe and gain understanding into the system of study through continual, adaptive experimentation. This helps to reduce risk and maximizes the probability of meeting mission goals.

The development of MSAL was driven by needs to address research into Uncertainty Quantification. Our need was to extend the dimensionality of existing techniques while applying analytics tools that help improve the fidelity of complex system modeling and simulation. MSAL is representative of the types of improved systems engineering tools that will be needed to address future challenges. It is only a small step toward our ability to communicate the intersection of risks, trust and uncertainty in future systems.

INCOSE Technical Operations Policy

Other analogy to a VSE is the INCOSE Technical Operations 2017 policy review initiative. The 2017 Technical Operations policy review includes INCOSE policies found in Table 5 below.

Table 5. INCOSE Technical Operations Policies

Policy	Description
TEC-100	Technical Infrastructure
TEC-101	Sale and Distribution of Technical Information
TEC-102	Approval of Collaborations
TEC-103	Standards
TEC-104	Journal Editorial Policy
TEC-105	Access to INCOSE Event Results & Technical Information
TEC-106	Translation of INCOSE Products

These policies can be very complex and incorporate a broad range of the stakeholder groups across the organization. A robust process, summarized below, is used to facilitate the policy review. The name of the associated VSE WG DP is shown in parenthesis.

Identify and Model (Functional and Physical Model). At a composite level the relationship of Technical Operations policies need to be understood in context. This requires some level of modeling we call Model INCOSE. or each policy under review, the necessary INCOSE positions and leaders of fundamental stakeholder groups to be included in discussion are identified. Additionally, linkages to other organizations within INCOSE need to be identified. This helps us identify groups of stakeholders needed in the policy review. As an observation, the resulting group of stakeholders can be considered as a VSE working on each policy – teams of 25 or less.

Elicit (Requirements) and Define. In an effort to represent the legitimate interests of each stakeholder group, each policy is sent out to the VSE for discussion and collection of comments. The round of comments is intended to elicit and define the requirements from the VSE to ensure that each policy update effectively integrates the needs and interests of the stakeholders.

Integrate (Integration). In parallel with the elicitation and definition of requirements, the integration of comments takes place on the update of each policy. Each policy is updated from the comments and sent back to the VSE as major revisions take place. The intention here is to ensure effective requirements understanding for all stakeholders under representation. Additionally, the integration phase incorporates the references to other INCOSE policies to ensure that all interactions within INCOSE policies have been modeled for future enhancements. There are several iterations of the integration phase until each policy has been adequately addressed for approval by the VSE.

Submission (Product Deployment).. Once all stakeholder requirements from the VSE have been implemented and the references have been effectively modeled, the Technical Director will submit the set of policies to Ways and Means for finalization.

Continuous Review(Self-Assessment). Updates are never complete. Self-Assess and start the review process again.

Summary

As INCOSE we know big challenges lie ahead. History tells us that these challenges will take expertise and innovation from the full spectrum businesses across expanding domains. Our own INCOSE Vision 2025 (INCOSE) outlines these challenges and the future of systems engineering. VSEs can and must contribute in the solutions to the Grand Challenges of the 21st century. These challenges require not only solutions, but also the tools and techniques to arrive at those solutions in meaningful and efficient ways. VSE WG DPs are but a step in this direction. As VSEs, we need to take not only DPs, but all forms of process enablers to build our capability to participate. A successful VSE is one that recognizes the responsibility to tailor all available process information to their individual and stakeholder needs. Those VSEs that don't take this responsibility seriously cannot remain competitive. Figure 4 is taken out of INCOSE Vision 2025 and provides VSE competencies which mature along with processes.

Figure 2 INCOSE Vision 2025 Essential Systems Engineering Competencies

There are other takeaways from our experiences. Most notable is the idea that people matter. The best process environment is only as good as the people that implement it. The major takeaway we offer from a business perspective is that attention to developing process maturity is essential for a VSE. Whether at the early stage of company development or later in the company lifecycle, technical, management, people and business processes are essential. The VSE should develop processes within the context of a framework that builds and promotes business growth.

Finally, as an INCOSE-built VSE, we look forward to continued growth along with INCOSE strategic objectives. VSEs can become a powerful contributor to INCOSE membership growth if we can reach the 95 percent of the business population represented by VSEs. This that means a tremendous growth path for INCOSE. It has been suggested by the VSE WG that a VSE certification program could be established and implemented by certified auditors and reviewers. This certification could be a discriminator for VSEs that are on a process maturity path. Other ideas that improve INCOSE service to VSEs include expanded relationship with Project Management Institute (PMI). PMI is already a strategic partner with INCOSE and strengthening this alliance could be a very useful feature to VSE. VSEs can be impactful in the development of new techniques, tools and processes called for in the INCOSE Vision 2025. An improved approach to process maturity provides a good starting point for these future developments. Competency and transformation start with a good foundation in process and a compelling reason to accomplish next level of systems engineering capability for the benefit of the planet and humankind.

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Biography

Joseph Marvin, ESEP, is a career research and development systems engineer. His experience includes U.S. Air Force Research and Development Engineer – Space Systems, and industry experience with Lockheed Martin and SAIC. He is the founder of Prime Solutions Group, Inc and leads the SBIR/STTR research activity. Joe is the former Chair of the VSE WG and currently serves as the INCOSE Assistant Director for Internal Operations.

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John Cadigan is an undergraduate student in the Ira A. Fulton Schools of Engineering at Arizona State University. His major is Engineering Management with a concentration in Business Analytics. John is a student member of INCOSE and currently serving an INCOSE Internship supporting Technical Operations. He is also currently working as a teaching assistant for a financial engineering class, and working on a senior capstone project with L3 Communications.