The 4th International Symposium - Supercritical CO2 Power Cycles
September 9-10, 2014, Pittsburgh, Pennsylvania

INCREASING SYSTEMS ENGINEERING EFFICIENCY FOR NASA'S EARTH TO ORBIT GROUP AND SANDIA NATIONAL LABORATORY'S RECOMPRESSION CLOSED BRAYTON CYCLE R&D INITIATIVES WITH THE PROCESS MANAGEMENT TOOL VDOT™

ROGER HERDY
Chief Systems Engineer
CFD Research Corporation
Huntsville, AL USA
jrh@cfdrc.com

Damian Yañez
Director Vdot™ Solutions
ESI North America
St. Louis, MO USA
damian.yanez@esi-group.com

Roger Herdy started his career at the U.S. Air Force's Arnold Engineering Development Center, where he worked in the Special Projects group testing emerging aerospace technologies. He then joined the contractor community at NASA MSFC, where he managed the design and development of test facilities and served as a test engineer. He has managed diverse programs for both Commercial and Government customers in the areas of advanced technology, process and systems engineering, and functional prototypes that demonstrate proof of concept. With his strong program management background, he embraced Vdot over eight years ago, first with NASA and then with commercial initiatives. He holds two patents in propulsion, and multiple patents for advanced oxidizers pending. He holds a BS in Mechanical Engineering from the University of Kentucky and a MS in Engineering Management from the University of Tennessee. He currently is the Chief Systems Engineer for CFDRC in Huntsville, Alabama.

Damian Yañez is a senior process management consultant for ESI Group specializing in Vdot™ - a revolutionary process capture, execution and management tool. He received his Bachelor of Science in Aerospace Engineering and Master of Science in Engineering Mechanics degrees from Missouri University of Science and Technology. Damian spent 24 years at McDonnell Douglas/Boeing as a mass properties and structures engineering specialist where he worked on numerous aircraft, space, missile and electronics programs. During his time at Boeing, Damian was one of the key founders of the Vdot software product and was instrumental in spinning this technology out of Boeing. The Vdot technology was acquired by ESI, a global company specializing in world-leading virtual prototyping and process management solutions. He resides in St. Louis, MO.

ABSTRACT

A constant challenge to increasing the efficiencies in a systems engineering environment is the deployment of the best tools. A system engineering environment with the process management tool Vdot provides a user-centered, first-person perspective that enables users to interact with an engineered system naturally and provides users with a wide range of accessible tools. This requires an engineering model that includes the geometry, physics, and any quantitative or qualitative data from the real system. The user should be able to walk through the operating system for a given mission and observe how it works and how it responds to changes in design, operation, or any other engineering modification. Implementing and maintaining the ESI Vdot process management tool for various groups within NASA Marshall Space Flight Center Advanced Concepts Office (ACO) for trade studies on architectures for the Space Launch System is discussed. Because of the large number of analysis study cases being performed in the Earth to Orbit (ETO) group, there is a great need to document the process, enhance productivity, and provide tracking capabilities and metrics on customer demand, thus magnifying ACO customer satisfaction. This service is being provided to ACO using the ESI Vdot tool. Roger Herdy is supporting Sandia National Laboratories in developing and commercializing the supercritical carbon dioxide recompression closed Brayton Cycle initiative. These efforts are envisioned to be managed with Vdot, showcasing the tool for both terrestrial power generation and deep space ETO applications. This paper describes how Vdot will help ensure success for both.

INTRODUCTION

Planning for projects is paramount for execution success, and more often than not, the central approach employed by most organizations heralds back to the methodology first implemented by Henry Laurence Gantt, an American engineer, social scientist, and inventor of the Gantt chart, the most common form of visually showing a project plan and progress. Gantt is noted for his humanizing influence on management, and for emphasizing the benefits of developing conditions that have favorable psychological effects on the worker.

The Gantt chart, for which Henry will be remembered, is a visual display chart based on time only, not on quantity, volume, or weight. It is a horizontal bar chart that graphically displays time relationships. In effect, it is a "scale" model of time, because the bars are different lengths depending on the amount of time they represent. Gantt charts provide a method for determining the sequence and simple logic of particular tasks and actions, which need to be taken to achieve a given objective. And by following the sequence, assuming it is correct, a project can be executed. If the sequence is incorrect, revisions are made while the project is put on hold.

A PERT (Program Evaluation and Review Technique) chart, conversely, is a pure logic representation of the project, with no time scaling, but with detailed logic relationships. Originally developed by the US Navy in the 1950s, it does not show the time factors involved. Modern computerized planning software enables both Gantt and PERT charts to be produced from the same database of information, plus more sophisticated bar chart representations, with resource and costing. However, most planning and execution software tools do not supply a real-time, critical path analysis, or the ability for the manager to quickly see the broad picture. And the average staff assigned to a project is usually lacking assignment priorities based on the critical path, and in most cases learns of the priorities via a series of team staff meetings.

To succeed in improving the efficiency of any team, the processes employed must first be captured to a sufficient level of detail to understand the flow of information or deliverables required to produce the required end product/s. To do this, most schedule facilitators gather a group of subject matter experts together to create a process diagram or value stream map. Typically, they use poster paper and sticky notes to capture the information, then manually transfer that data to a picture in PDF format, Microsoft PowerPoint, or Visio. Unfortunately, this is a painstaking effort and errors often occur in the transfer of information. Also, it is frequently difficult to arrange for all key parties to physically be together in a room to collaborate on the process definition. In addition, the diagrams are static, with no easy way to deploy them to individuals and/or teams. Testing of the processes is essentially an academic exercise, and the documentation quickly becomes outdated and unused.

The core research behind Vdot™ originated within Boeing's Phantom Works unit in coordination with the Defense Advanced Research Projects Agency. The name is derived from the mathematical symbol for the derivative of velocity which is acceleration. Vdot is now a commercial-off-the-shelf process management tool from ESI Group that provides the ability to define, deploy, and execute desktop processes for teams in a distributed network environment. Vdot provides the ability to route data, launch tools (IT applications), and also provides automatic real-time project status. Vdot's capabilities have been used on a wide variety of engineering and business processes. Project teams experience reduced data chase, rework, and status reporting effort while enabling greater project and process visibility.

NASA'S EARTH TO ORBIT ARCHITECTURE ANALYSIS

Within NASA Marshall Space Flight Center Advanced Concepts Office (ACO), trade studies are required on architectures for the Space Launch System (SLS). Because of the large number of analysis study cases being performed in the Earth to Orbit (ETO) group, there is a great need to document the process, enhance productivity, and provide tracking capabilities and metrics on customer demand, thus magnifying ACO customer satisfaction. This service is being provided to ACO using the ESI Vdot tool.

The ETO group is looking at various SLS heavy lift vehicle architectures, and is tasked to answer these questions: Will it work? What will it look like? What is the preliminary design?

Figure 1 (courtesy of NASA) shows the overarching mission areas of the SLS.

Figure 1. Overarching Mission Areas of the Space Launch System

ACO utilizes multi-disciplined teams within the office to provide fully integrated assessments of missions and their elements (i.e., the components that make up the architecture for any given vehicle). The ACO Design Teams are established, co-located teams of systems and design engineers. Other disciplines or specific expertise are matrixed into the team as necessary.

SANDIA NATIONAL LABORATORY'S S-CO2 R&D INITIATIVES

Sandia National Laboratories (Sandia) took the lead in investigating the supercritical carbon dioxide (S-CO2) Brayton cycle using internal research and development funds beginning in 2007. Initial investigations focused on the stability of S-CO2 as a working fluid very near the fluid's critical point – a thermodynamic state in which fluid properties vary dramatically. With early positive results, the Department of Energy (DOE) funded development of a more extensive test article. This test article has proven successful, leading to DOE requesting $57M for R&D in the FY15 budget, $27.5M of which is for a pilot called the Supercritical Transformational Electric Power generation (STEP) initiative. The DOE goal is to make electricity as efficiently as possible with a cost-effective system. This initiative is important to our Nation, as a one percentage point improvement in efficiency over the typical steam plant efficiency of 33% reduces greenhouse gas emissions by an estimated 2.9%. Increasing efficiency to 50% as Sandia intends to demonstrate would reduce emissions by 34%. Consumer costs will also decline as efficiency improves and fewer natural resources are consumed. **Figure 2** (courtesy of Sandia) shows the test article and the overarching footprint that the S-CO2 can interface with, along with technology development such as turbomachinery. A video describing this current test article can be seen at http://youtu.be/qiMuFiO17hs.

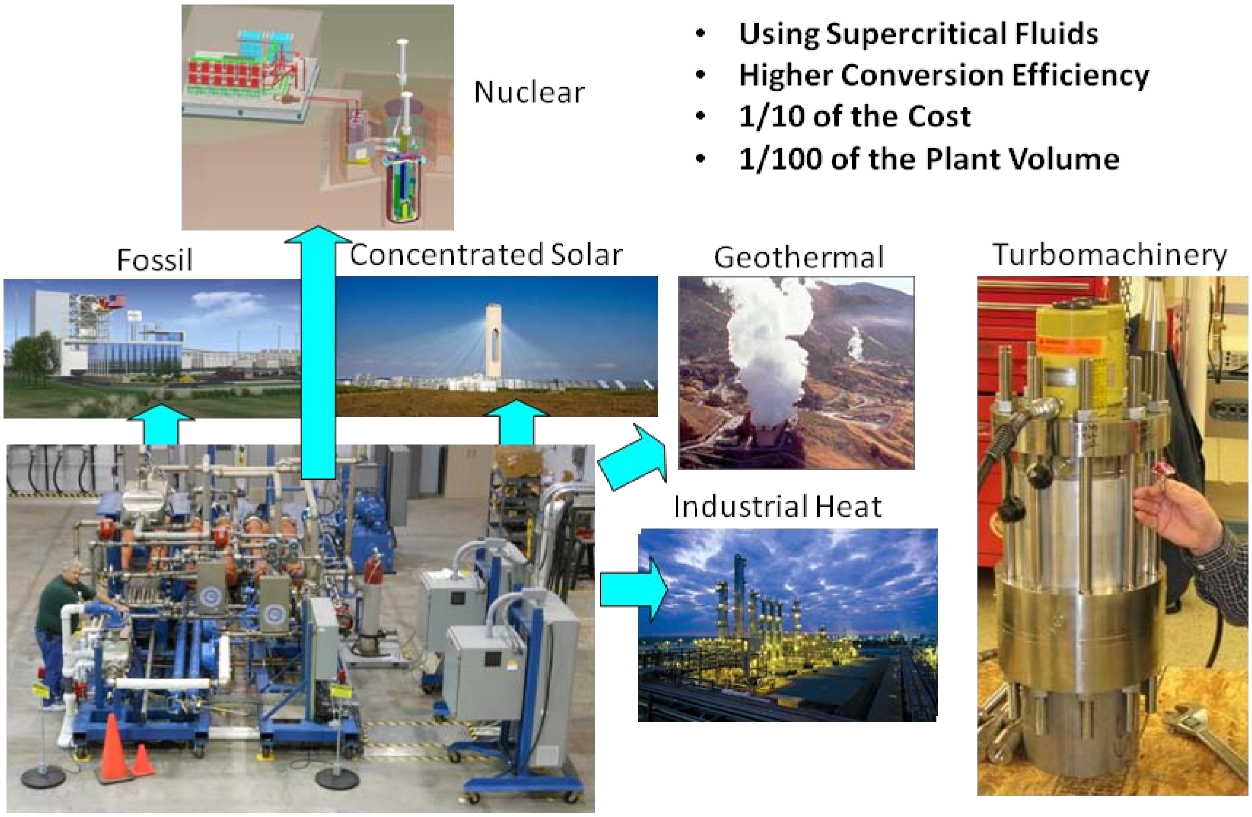

Figure 2. Sandia Test Article and Overarching Footprint

PROCESS MANAGEMENT WITH VDOT

Sandia is considering the use of Vdot to manage the proposed STEP initiative. To achieve significant improvements with any project, the processes currently being employed must first be understood. This includes identifying the scope of the processes, i.e., what products are to be created (output) and what is needed to create them (tasks, tools, time). Once the objectives are defined, the activities required to achieve those products, along with the associated inputs and deliverables for each step, can be described.

Vdot's point and click graphical interface (see **Figure 3)** allows quick and easy definition of processes electronically using "Smart Tasks" in "Smart Processes". Smart Tasks are analogous to kits in the lean factory in which everything an assembly worker needs for the job at hand is gathered into a package and delivered to the point of action. Similarly in the office or electronic environment, Vdot Smart Tasks include a complete description of what needs to be done, when, and by whom, and defines the inputs and required outputs for each task. Vdot then makes it easy to define the flow of information among process participants to provide a true awareness of "who needs what from whom". This visual map helps identify undocumented steps within the processes that may be significantly impacting throughput. It also highlights areas where tasks are being worked sequentially that could actually be worked in parallel. This is significantly different from a Gantt chart, yet Vdot can take a Gantt chart from Microsoft Project and use it to make an initial process thread, which accomplishes two things: it shows "dead ends" or unconnected tasks that are an indication of a Microsoft Project file with low fidelity; and the initial process thread can be expanded and refined upon to capture the true nature of "who needs what from whom". After this expansion and refinement, Vdot can also export to a Microsoft Project file, often with a higher degree of fidelity.

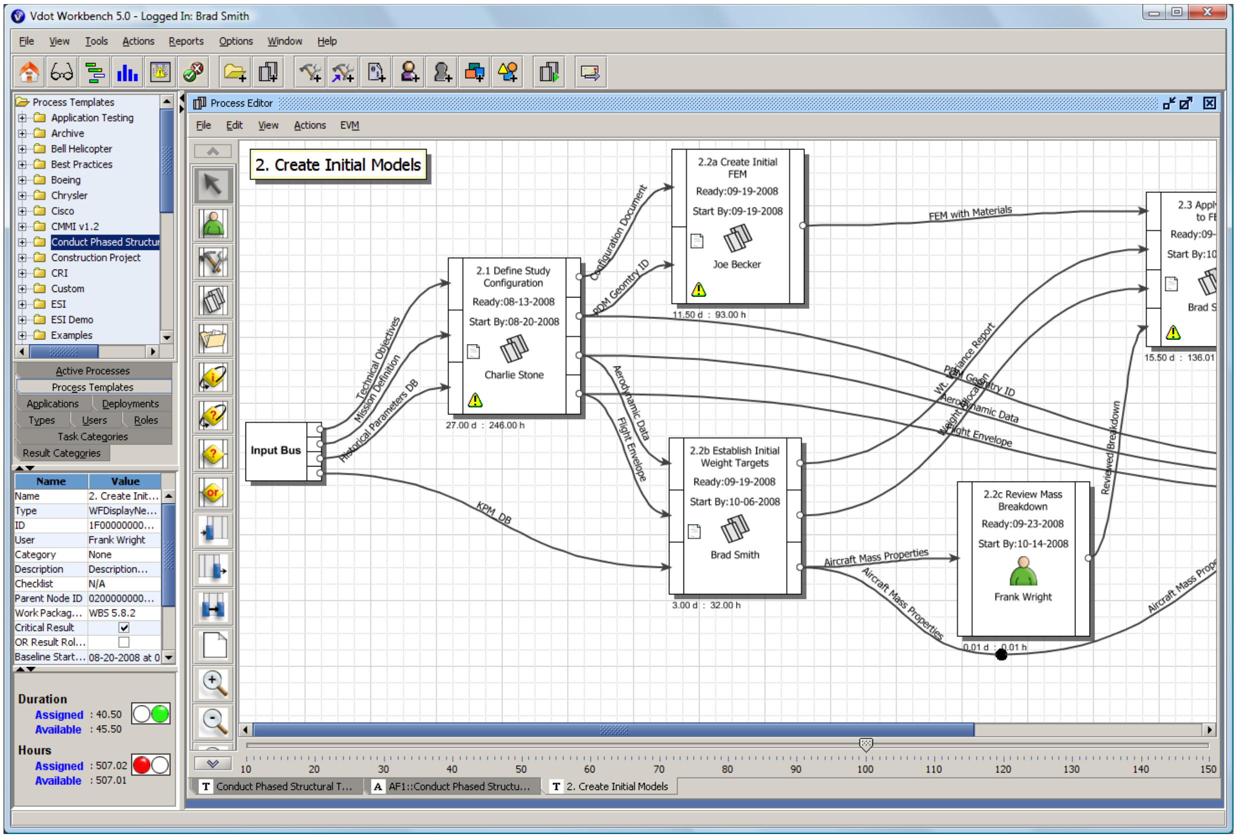

Figure 3. Defining Value Streams using Vdot's Process Editor

As previously mentioned, the Gantt chart is a common tool to manage a team through the execution of a project. As **Figure 4** shows, the task sequence and schedule are well-defined, and Gantt chart software also allows definition of how much effort from whom is required. Unfortunately, the Gantt chart does not show why the tasks are sequenced as they are.

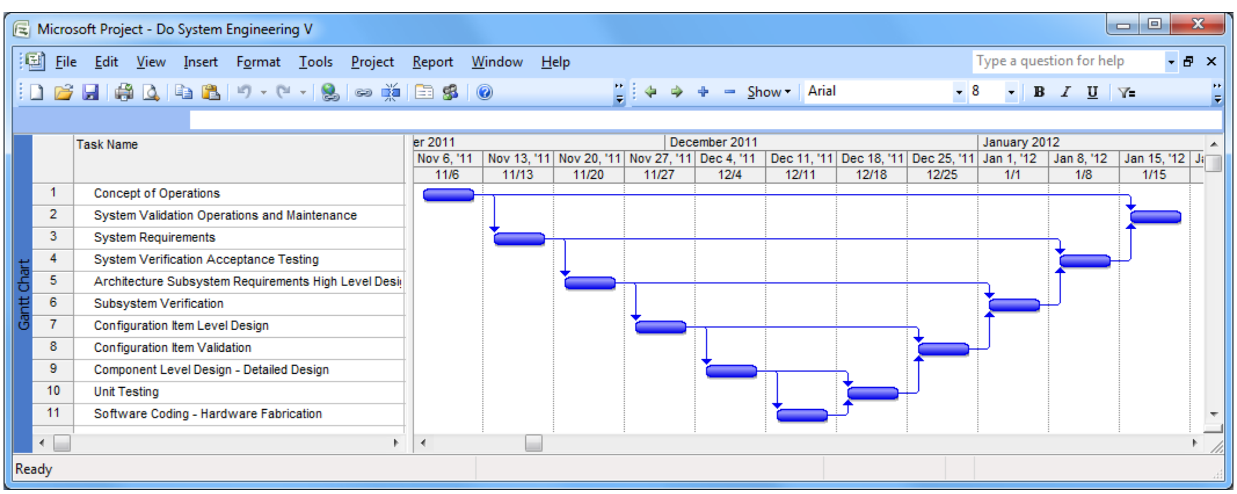

Figure 4. Gantt Chart

In systems engineering in particular and product development in general, the information flow dependencies are the primary determinant of task sequence. The information in a Gantt chart can also be displayed in workflow view where each task is a box with arrow links to downstream successor tasks.

These workflow views do not, however, show the information flows, whereas workflow diagrams often do. **Figure 5** shows two of the shapes Microsoft PowerPoint have defined for drawing workflows. By having a special shape for data (actually, several), PowerPoint encourages workflow diagrams where activities are linked by the data outputs from predecessors as the inputs to successors.

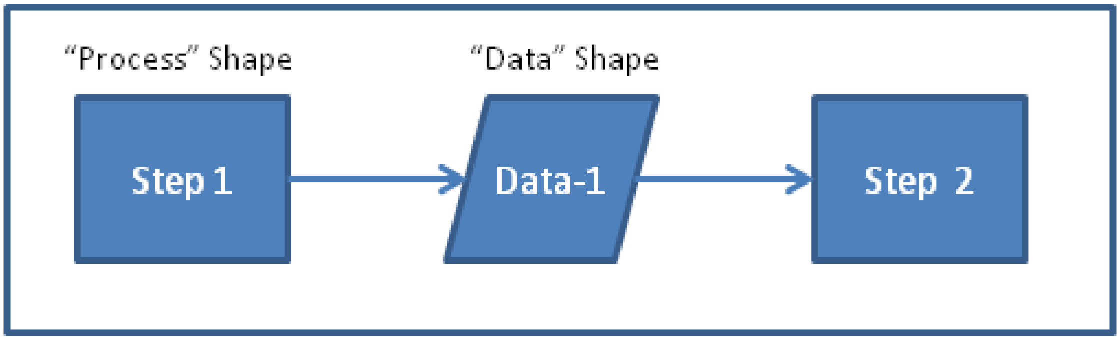

Figure 5. Microsoft PowerPoint Workflow Shapes

The information flow concept can be handled more formally by standards such as IDEF0, **Figure 6**, which shows the activity (or task) transforms the two inputs ("Issues" and "Operations Data") into an output ("Program Plan"). [The top arrow ("Program Charter") is a control: a resource that provides guidance or requirements to perform the activity. The bottom arrow ("Program Team") is a mechanism: a resource used to perform the task, but not consumed or transformed by the task.] In IDEF0, the information flows are visible due to arrow labels, not a special shape.

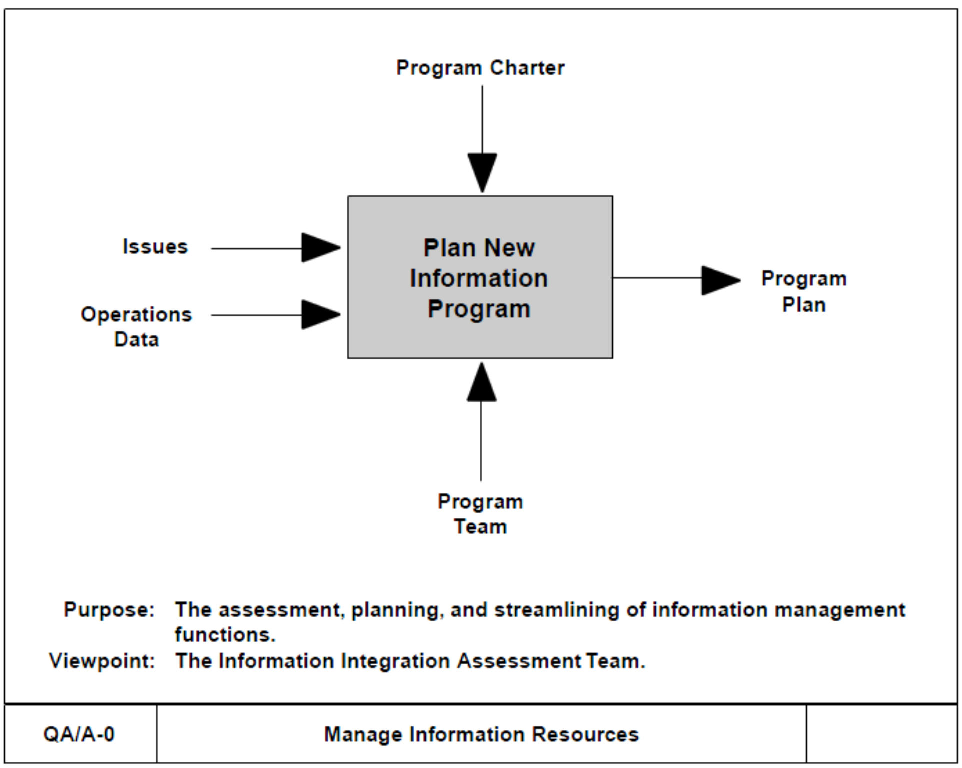

Figure 6. IDEF0 Activity (Defense Acquisition University Press, 2001)

Vdot takes a workflow definition approach similar to IDEF0; tasks are linked by labeled arrows indicating outputs being delivered to inputs. In addition, each task can hold duration and effort properties similar to Gantt charting software. With sequences defined by the information flows, the plan schedule and properties such as the critical path can be calculated just as with other Gantt chart packages. At the atomic level of Vdot is the “Smart Task”, shown in **Figure 7**. Smart Tasks are analogous to kits in the lean factory in which everything an assembly worker needs for the job at hand is gathered into a package and delivered to the point of action. Once the process is understood, which includes identifying the scope of the processes, i.e., what products are to be created (output) and what is needed to create them (inputs, and instructions such as work, embedded tools, time), a Smart Task can be created. Smart Tasks include a complete description of what needs to be done, when, and by whom, and defines the inputs and required outputs for each task. The tasks can be linked to define a workflow (as was shown in Figure 3) and then viewed either in PERT or Gantt form.

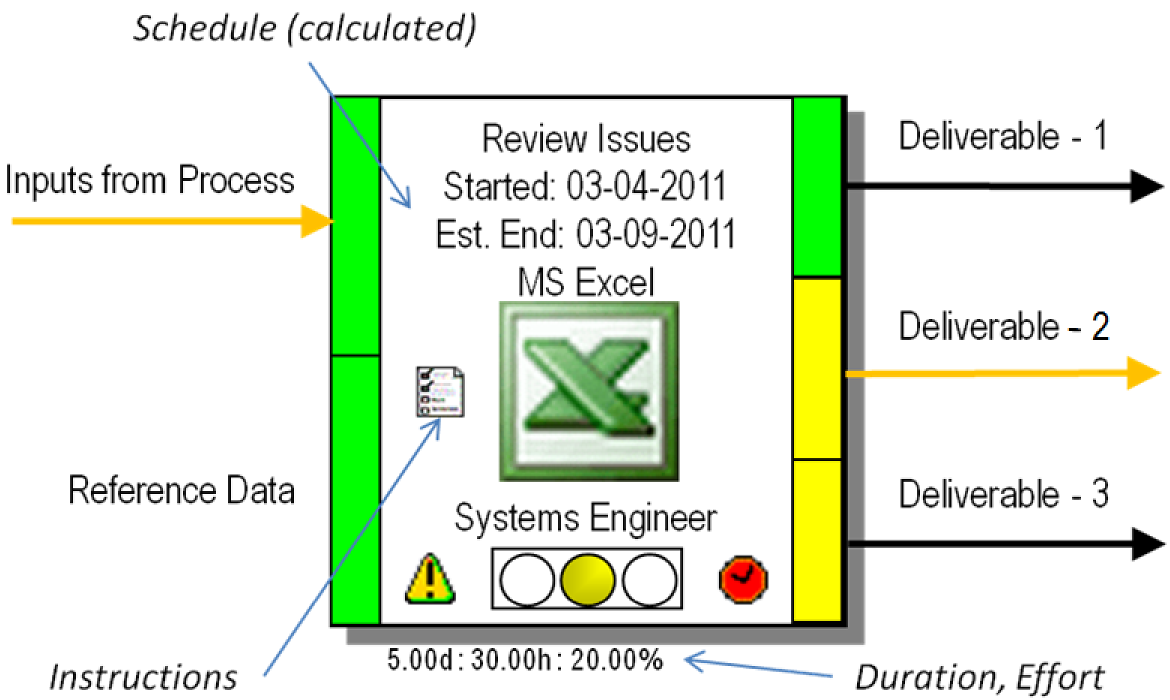

Figure 7. Vdot Workflow Task with Project Management Parameters

Once desired processes have been established, another key element of problem-solving is control. This means ensuring that teams execute best practices repeatability. Vdot’s visual process control system immerses teams into the defined processes, and helps them perform their assignments in the most effective and efficient sequence. Since all the information they need for each Smart Task is supplied through the process, data chase is eliminated and rework is minimized. All participants understand the sources of their data and what they need to produce in order for others to successfully complete their assignments. Task priorities are established for individuals based upon dynamic critical path calculations. Deviations or modifications to processes are captured for future analysis and improvement efforts.

The typical metrics to be analyzed to maximize process velocity or reduce complexity are inherent to the Vdot process definition. Again, Vdot’s visual interface and database enable tracking the actual information flow to see where unwanted rework (defects), process iterations (motion), and bottlenecks (wait times and overproduction) are inhibiting progress. The feature of the built-in dashboards drives directly into typical sources of non-value added work. Resource loads may be viewed on a team or individual basis (**Figure 8**). Conflicts are also readily apparent and predicted so adjustments can be made proactively before schedule is impacted.

This tool logs the time when a task is ready to start and when it is completed, and maps the task process flows in hierarchal, nested maps. Since the tool actually links the work needing to be performed to the manager who needs real-time information on task process status (and thus rolling up the overall project status), it gives a unique opportunity to increase the efficiency of the project processes.

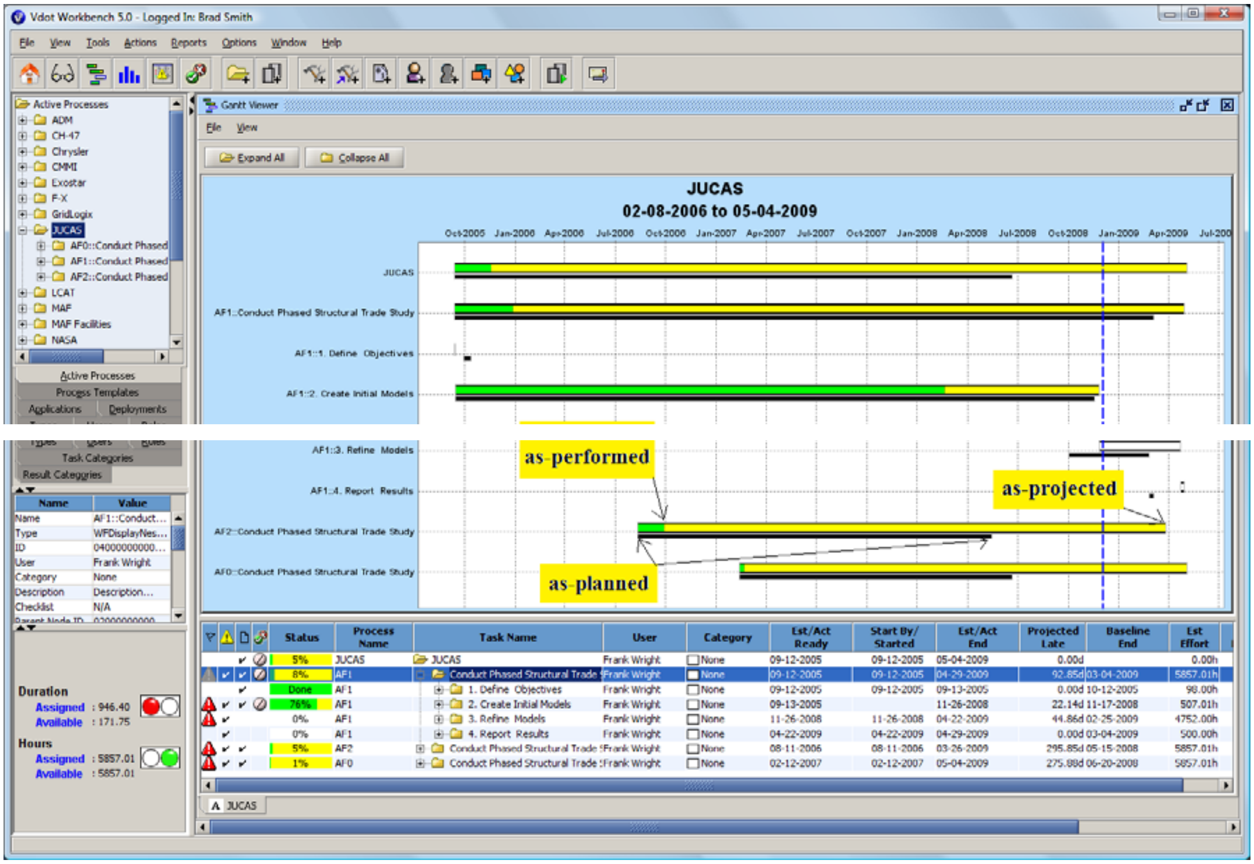

Figure 8. Vdot Dashboard Showing Assignments, Metrics, Status

The ETO SLS Evolvability Study Case Execution template was put into production in late November 2013. This process template is repeatable and reusable for all ETO SLS study cases. Once fully activated (as was done in January 2014), multiple Vdot study cases can run simultaneously. A name for each study case is provided by the SLS Study Case Lead during activation. Upon activation, the SLS Study Case Lead generates assignments, and data files are routed according to the process flow in Vdot. Email notifications are automatically sent to the appropriate individuals when their tasks become ready. Each user has their own task list with their assigned tasks. Each task includes everything they need to perform the task at hand. These Smart Tasks hold the complete definition of the task to be done: the inputs and required outputs, the task assignee, the projected schedule, the duration (days), the effort (man-hours), and a detailed description of the activity. Also the state of the data being analyzed is captured for each step in a database.

Progress is automatically tracked at the individual, team and project levels. Task priorities and timelines are linked across ETO. Real-time status information and metric reporting is available to all team members and management at any time. Management can quickly see the status of a Study Case and can also identify bottlenecks, resources constraints and opportunity for process improvement.

A feature available in Vdot, iterating to a solution, is also featured within this work. **Figure 9** shows an example of this type of iterative sub-process included in the ETO analysis template. With each iteration, a decision is made as to what analysis to perform next based upon the results of the previous iteration, or to end the process and produce a report in the form of a “baseball card” which summarizes the specific architecture for the mission requirements.

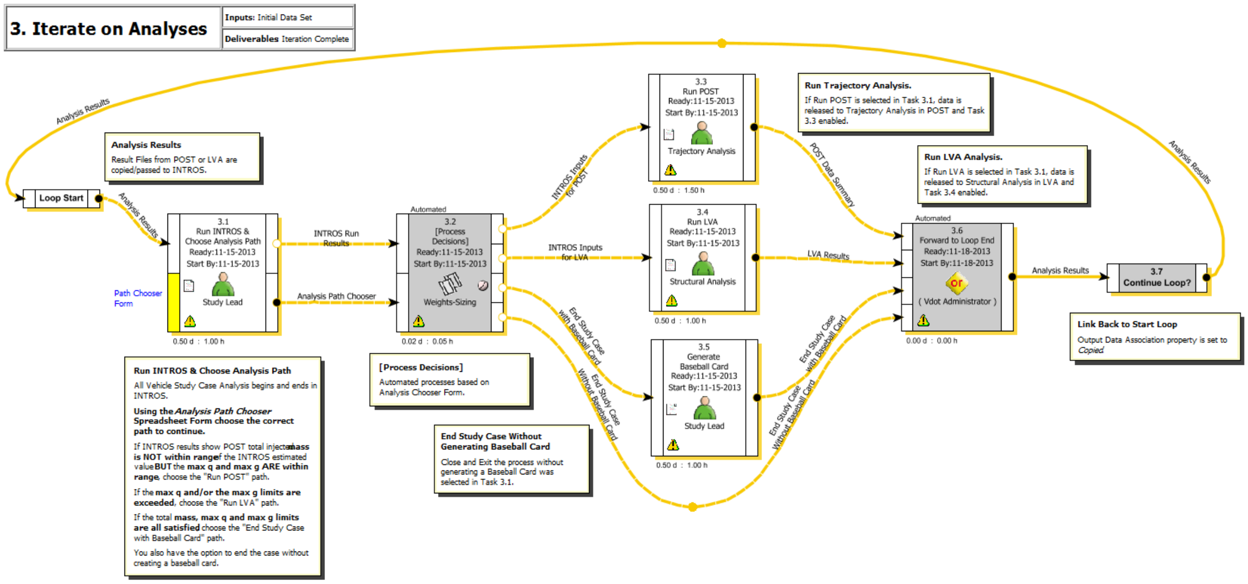

Figure 9. Iteration Analysis Vdot Template for NASA's Advanced Concepts Office

Since process implementation, the users have been very receptive to using this tool. ETO management can see the status of all projects at a glance, and can troubleshoot more effectively. If a team member is away from the office, tasks can be reassigned with ease. Notifications are sent when tasks run behind schedule. The software tracks how long it takes to complete analysis tasks, which proves useful in providing time estimations for new, similar tasks. The tool is used either on the NASA LAN or via the internet, so users can connect anytime and anywhere to conduct their trade studies. Run times have improved from weeks to hours, and productivity has soared. As can be seen in **Figure 10**, the team is now able to analyze many more vehicle configurations in a much shorter period of time.

MSFC personnel are also developing and implementing automated processes using the Vdot tool for the Project Coordination Office in ACO. This customized tool aids in collecting and tracking project data necessary to meet reporting and evaluation requirements. Data can be automatically consolidated if required. Data includes charts, reports, schedules, plans, etc. Current implementation includes task assignments, automatic reminders, input verification, document tracking, and data consolidation. At any given time, the Project Coordinator can easily identify what group/individual has not submitted required data necessary for project communication.

In all processes, different levels of permissions ranging from low level/read-only to administrator (who can edit every step of the process) were established. This way, all users have appropriate access to the program, and only trusted individuals can make significant changes.

Color coding indicates the existence and states of the data items, and the states of the tasks. Experience has found the management reports, such as task lists and Gantt charts tied to the process state, particularly helpful. Using Vdot, as a process is executed, all tasks are well-defined, all needed inputs are present, and all defined outputs could be made from the inputs. By modeling information flows and project management parameters together, better project plans result. By managing the work and project status together, teams can more easily follow improved plans, less effort is spent on status gathering, and better status information is achieved. In addition, as-performed metrics are provided automatically, which will be invaluable for future improvement efforts.

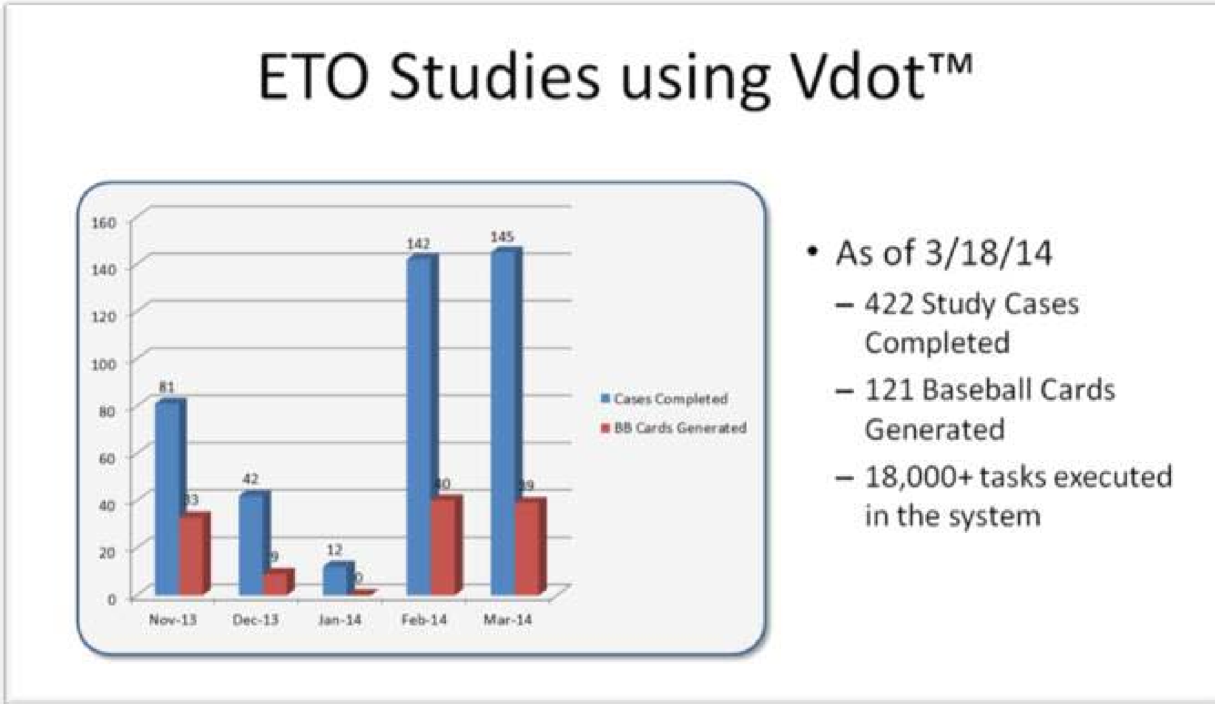

Figure 10. Reduction in Run Times for ETO Architecture Studies using Vdot

S-CO2 BENEFITS

As can be seen in **Figure 11**, the use of supercritical carbon dioxide can produce energy conversion efficiencies significantly higher than that for steam, the current standard working medium. The major drawback to using the traditional steam cycle is that most of the heat that remains in the steam after it leaves the turbine must be rejected from the fluid to turn it back into liquid water that can be recompressed and sent through the cycle again. This heat energy cannot be transferred back into the liquid leaving the compressor because both flows are at very nearly the same temperature. The rejected heat represents a large fraction of the heat that is put into the system at the heater, which results in a significant hit to cycle efficiency. In contrast, most of the heat that remains in the S-CO2 after it leaves the turbine is recuperated within the system. That is, most of the heat is put back into the cold fluid exiting the compressor before it enters the heater. This is because the S-CO2 does not have to undergo a constant temperature phase change to reject heat. A useful temperature difference exists between the fluid exiting the turbine and the fluid exiting the compressor. Only a small amount of heat needs to be rejected from the cycle to get the S-CO2 at the right density to recompress it.

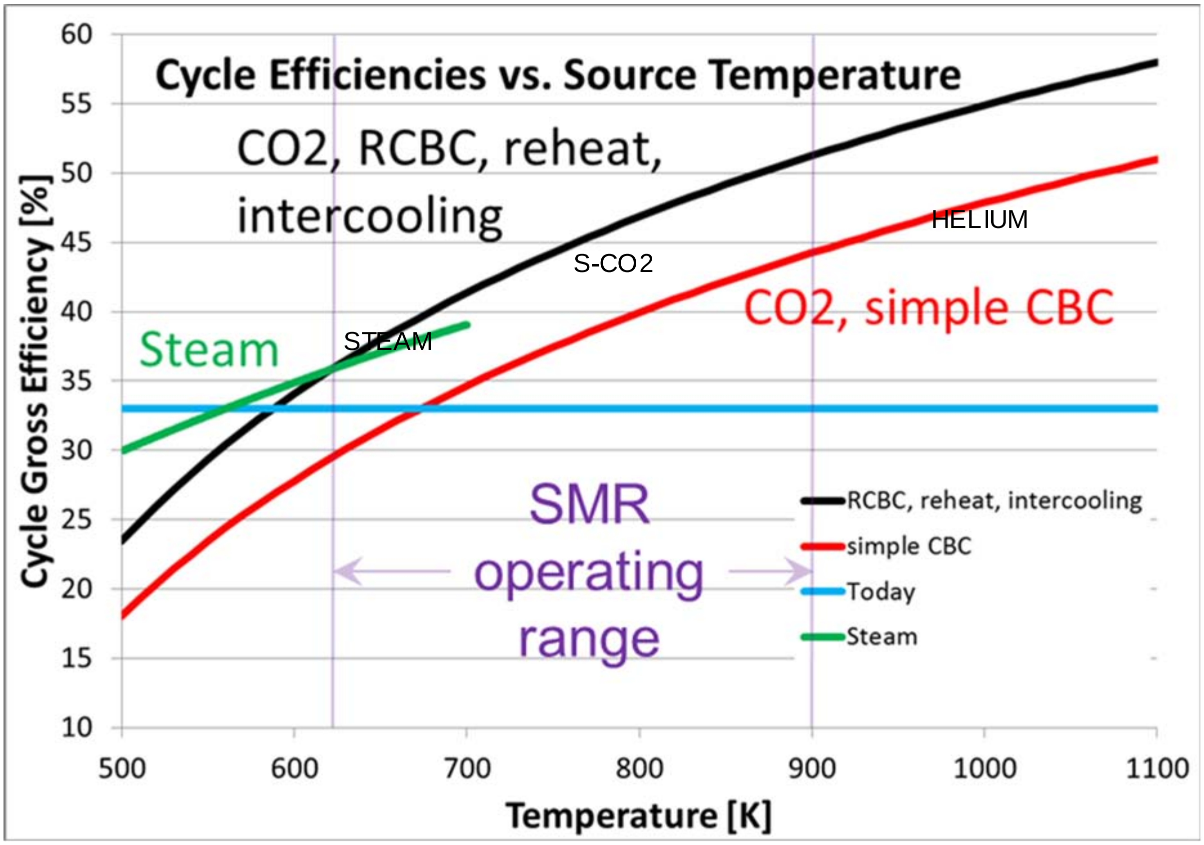

Figure 11. Cycle Efficiencies Versus Source Temperature

The thermodynamics that describes the compression, heating, and expansion of the S-CO2 is actually the same as for a jet engine. The difference is that the S-CO2 closed loop cycle takes the turbine exhaust and reuses it. The first closed Brayton cycle power plant was built in 1939 at the Escher Wyss factory in Zurich, Switzerland. The power plant used air instead of S-CO2. Escher Wyss built a number of these power plants, often with waste heat used to heat homes in town (cogeneration). Sandia first produced more electricity than it consumed in the Turbine-Alternator-Compressors (TACs) in March 2010, on a single TAC loop. Sandia has the first and only known closed loop recompression S-CO2 Brayton cycle in the world, making it a unique and valuable testing system. The S-CO2 TAC and related system is so small that it has been considered for several space-based power generation applications, including powering an ion drive space tug to move orbiting debris away from satellites, and for auxiliary power generation for manned missions to Mars.

S-CO2 power conversion technology offers a number of benefits over competing cycles. These include:

- S-CO2 is a very benign fluid. Instead of a fire hazard, it will actually help to suppress fires should an accidental pipe break occur. For this reason, the cycle can be used to generate power in areas where minimizing fire hazards is essential.
- The fluid remains in a relatively dense state; therefore, components are very small compared with traditional steam cycles. This reduces material costs, reduces facility size, and enables applications that require significant power in a small volume.
- The thermodynamic cycle can generate power over a wide range of commonly available heating temperatures. This is because the critical temperature of CO2 is a very low 87°F, and theoretically, any heat source above this temperature can sustain an S-CO2 power generation cycle. Other common cycle fluids – most notably water – require significantly higher temperatures.
- S-CO2 is compatible with common building materials, therefore avoiding the need for costly R&D for specialized materials and components.

- Through a heat rejection process called ‘dry cooling,’ the cycle offers an economical electricity-generation solution in areas that cannot provide cooling water. The high solar heat availability in the desert, coupled with dry cooling, make the S-CO2 cycle ideal for Concentrated Solar Power applications.

SYSTEMS ENGINEERING CONSTRUCT PROPOSED BY CFD RESEARCH CORPORATION

CFDRC sees some programmatic challenges to S-CO2 development and the success of the proposed STEP initiative. CFDRC has recognized the need for a strong systems engineering approach to facilitate the development of S-CO2 technology and the execution of R&D initiatives such as the STEP program in general. We will offer compliance with DOE Nuclear Safety Framework Applicable to the S-CO2 R&D and the STEP Initiative, which is a hierarchical set of governing documents that starts with policies (i.e.: sets high level expectations); rules and orders (provides requirements); guides and standards (provides acceptable methods and criteria). This framework is defined in DOE Order 251.1C, Departmental Directives Program, and DOE Order 252.1, Technical Standards Program. We offer the following systems engineering construct, which basically follows the following steps: a) Risk Identification and Mitigation Planning / Execution; b) Requirements Analysis and Documentation; c) Process and Program Management; and d) Technology Readiness Level (TRL) Tracking and Deliverables (which includes a special SharePoint module developed for the US Space and Defense Missile Command and the DOE Project Assessment and Reporting System (version II). We fully recognize that this approach will satisfy the need to follow the DOE Directives and Technical Standards Hierarchy, shown in **Figure 12**. **Figure 13** shows the layout of our systems engineering construct. The companies listed in this diagram, 3SL and ESI Group are in discussions with CFRDC for support to the proposed STEP initiative. CFDRC personnel have a long-standing and successful work history with these two companies, and have the knowledge to bring on additional expertise if necessary.

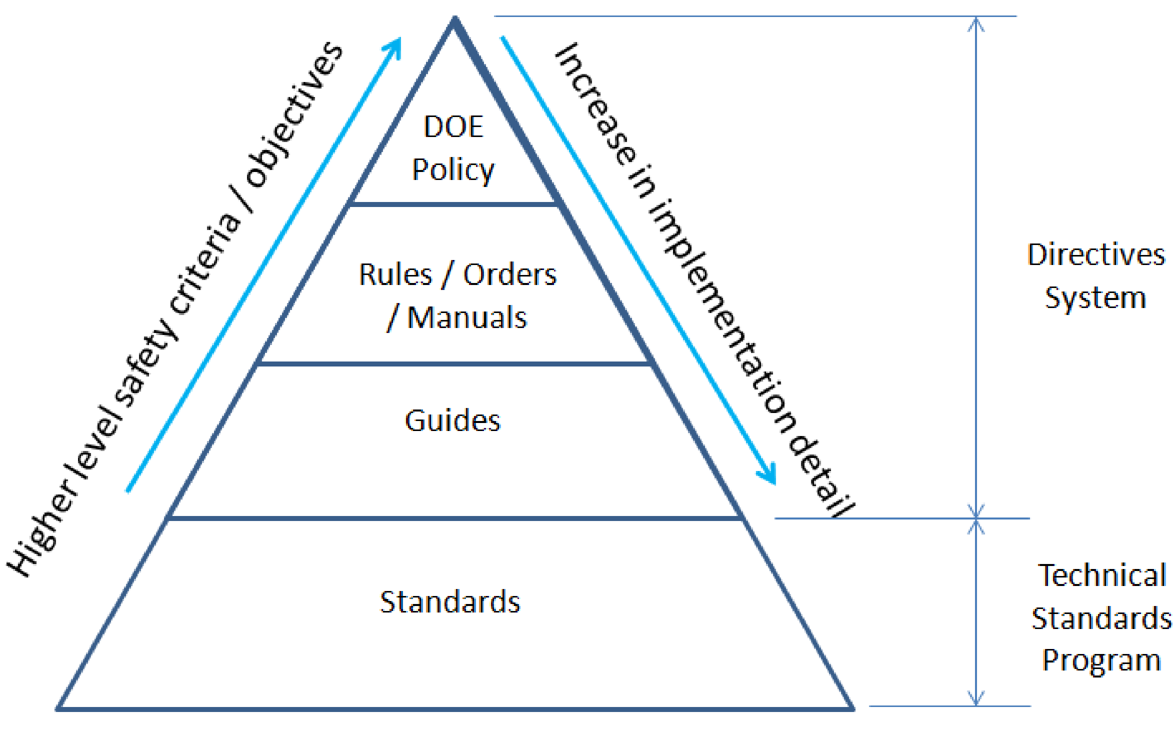

Figure 12. DOE Directives and Technical Standards Hierarchy

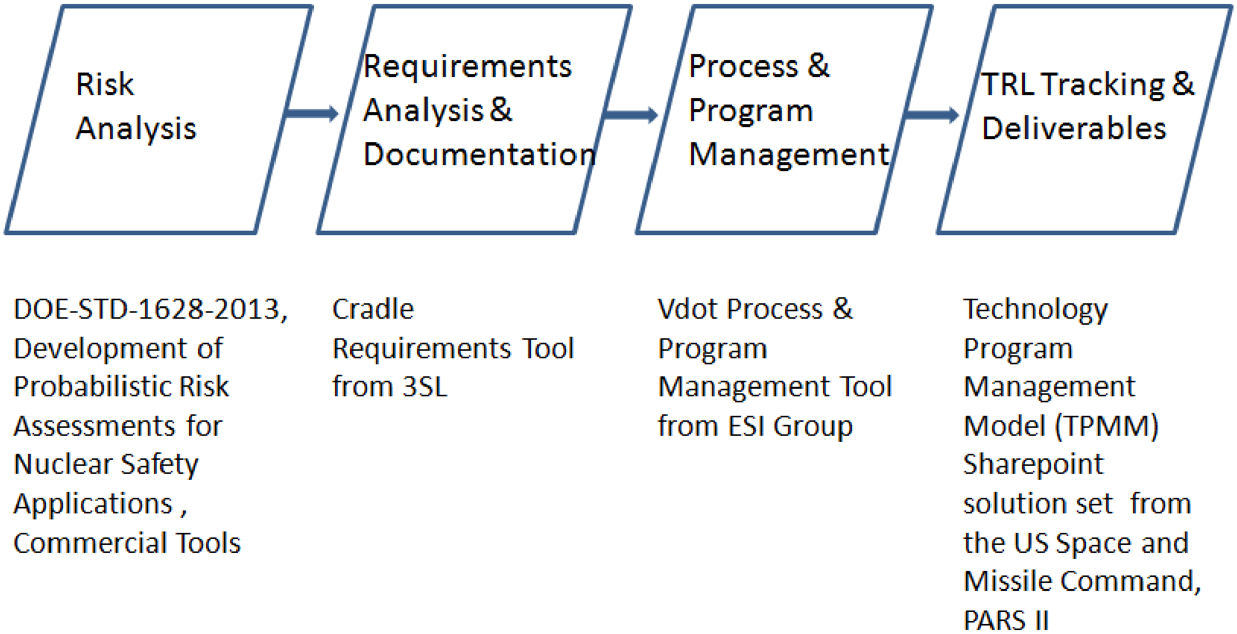

Figure 13. CFDRC Systems Engineering Construct for DOE S-CO2 R&D Initiatives

If the Sandia Brayton STEP project R&D effort moves toward the full validation of these features, the DOE has a very specific set of instructions that will guide the program. Available online at www.directives.doe.gov, the document "Managing Design and Construction Using Systems Engineering for Use with DOE O 413.3A" will serve as the management cornerstone of a major demonstration initiative. Within this guide are a set of process instructions for typical DOE acquisition management. **Figure 14** shows the Critical Decision (CD) milestones inherent in this Systems Engineering Guide.

The DOE Acquisition Management System establishes principles and processes that translate user needs and technological opportunities into reliable and sustainable facilities, systems, and assets that provide a required mission capability. The system will be organized by project phases and CDs, progressing from broadly-stated mission needs into well-defined requirements resulting in operationally effective, suitable, and affordable facilities, systems, and other products.

Within DOE, projects typically progress through five CDs, which serve as major milestones approved by the Secretarial Acquisition Executive. Each CD marks an authorization to increase the commitment of resources by DOE and requires successful completion of the preceding phase or CD. The amount of time between decisions will vary. The CDs are:

- CD-0, Approve Mission Need. There is a need that cannot be met through other than material means;
- CD-1, Approve Alternative Selection and Cost Range. The selected alternative and approach is the optimum solution;
- CD-2, Approve Performance Baseline. Definitive scope, schedule, and cost baselines have been developed;
- CD-3, Approve Start of Construction/Execution. The project is ready for implementation; and
- CD-4, Approve Start of Operations or Project Completion. The project is ready for turnover or transition to operations, if applicable.

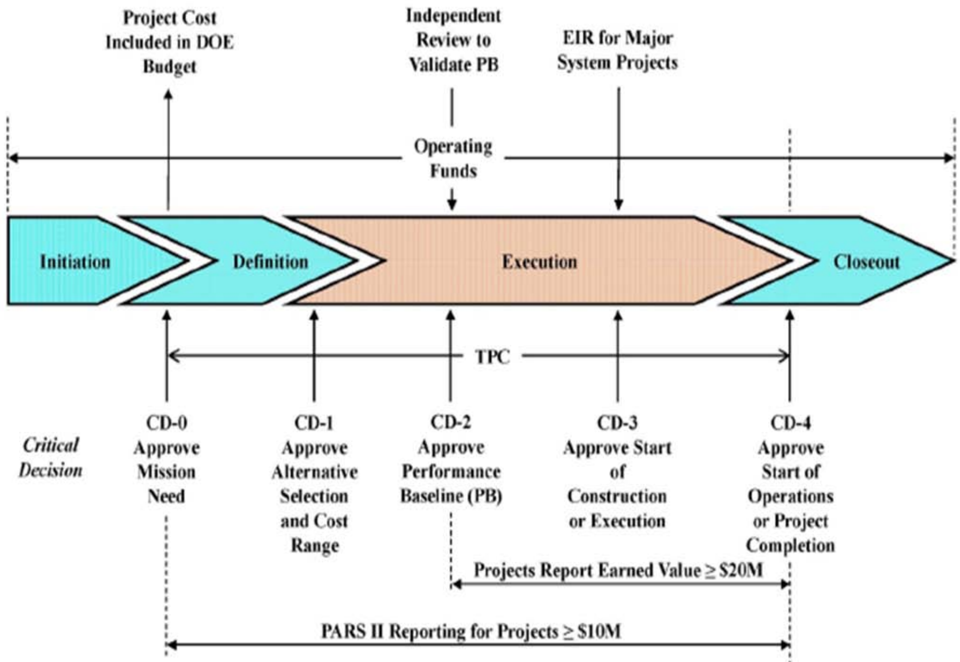

Figure 14. Typical DOE Acquisition Management System

The following representative table (**Table 1**) contains an example of the process steps required for a sample CD. The process steps for each CD have been modeled in Vdot, and the overall top-level view of all the nested CDs is shown in **Figure 15**. For the referenced "Prior to CD-1" section listed below, the expansion of the nested Vdot process is shown in **Figure 16**. This reflects the process steps required for the "Prior to CD-1" section from the previously referenced DOE Systems Engineering Guide, and future work will be to define the processes inherent to each step shown in the table. This way, a complete and thorough mapping to the entire sequence of steps contained in the DOE Systems Engineering for each CD, and can be made available for use throughout the DOE.

Table 1. Representative Table from DOE Systems Engineering Guide

Prior to CD-1	Approval Authority[2]
Complete a Conceptual Design.	
• Document High Performance and Sustainable Building provisions per EO 13423, Section 2(f), EO 13514, Section 2, and Sustainable Environmental Stewardship considerations per DOE O 450.1A, as amended, in the Conceptual Design Report, Acquisition Strategy, and/or PEP, as appropriate. (Refer to DOE G 413.3-6 and DOE O 430.2B.)	
• Conduct a Design Review of the conceptual design with reviewers external to the project.	
• *For nuclear facilities, a Code of Record shall be initiated during the conceptual design.*	
• Complete a Conceptual Design Report. Refer to Appendix C, Paragraph 4.	
Prepare a Preliminary Hazard Analysis Report (PHAR) for facilities that are below the Hazard Category 3 nuclear facility threshold as defined in 10 CFR Part 830, Subpart B.	Field Organization
Develop and implement an Integrated Safety Management Plan into management and work process planning at all levels per DOE M 450.4-1.	
Establish a Quality Assurance Program (QAP). (Refer to 10 CFR Part 830, Subpart A, DOE O 414.1C, and DOE G 413.3-2.) *For nuclear facilities, the applicable national consensus standard shall be NQA-1-2008 (Edition) and NQA-1a-2009 (Addenda).*	
Identify general Safeguards and Security requirements for the recommended alternative. (Refer to DOE M 470.4-1 and DOE G 413.3-3.)	
Complete a National Environmental Policy Act (NEPA) Strategy by issuing a determination (e.g., Environmental Assessment), as required by DOE O 451.1B. Prepare an Environmental Compliance Strategy, to include a schedule for timely acquisition of required permits and licenses.	
Update Project Data Sheet, or other funding documents for MIE and OE projects, and OMB 300s, if applicable. (Refer to OMB Budget Call for PDS and Exhibit 300 Template.)	
For Hazard Category 1, 2, and 3 nuclear facilities, prepare a Safety Design Strategy (SDS), with the concurrence of the CNS or with written advice of the CDNS, as appropriate, for projects subject to DOE-STD-1189-2008.	*SBAA and FPD*
For Hazard Category 1, 2, and 3 nuclear facilities, conduct an Independent Project Review (IPR) to ensure early integration of safety into the design process. (Refer to DOE G 413.3-9 and DOE-STD-1189-2008.)	*PSO*
Prepare a Conceptual Safety Design Report (CSDR)[3] for Hazard Category 1, 2, and 3 nuclear facilities, including preliminary hazard analysis. For a project involving a major modification of an existing facility, the SDS must address the need for a CSDR, as well as the required PDSA. (Refer to DOE-STD-1189-2008.)	*SBAA via the CSVR*
Prepare a Conceptual Safety Validation Report (CSVR), with concurrence from the FPD, on the DOE review of the CSDR for Hazard Category 1, 2, and 3 nuclear facilities. (Refer to DOE-STD-1189-2008.)	*SBAA*

Note that this table is for only one portion of the DOE Systems Engineering Process, and Figure 13 has “Prior to CD-1” as one of the top level, nested processes (circled in red to indicate which top level has been expended to show more details in Figure 16).

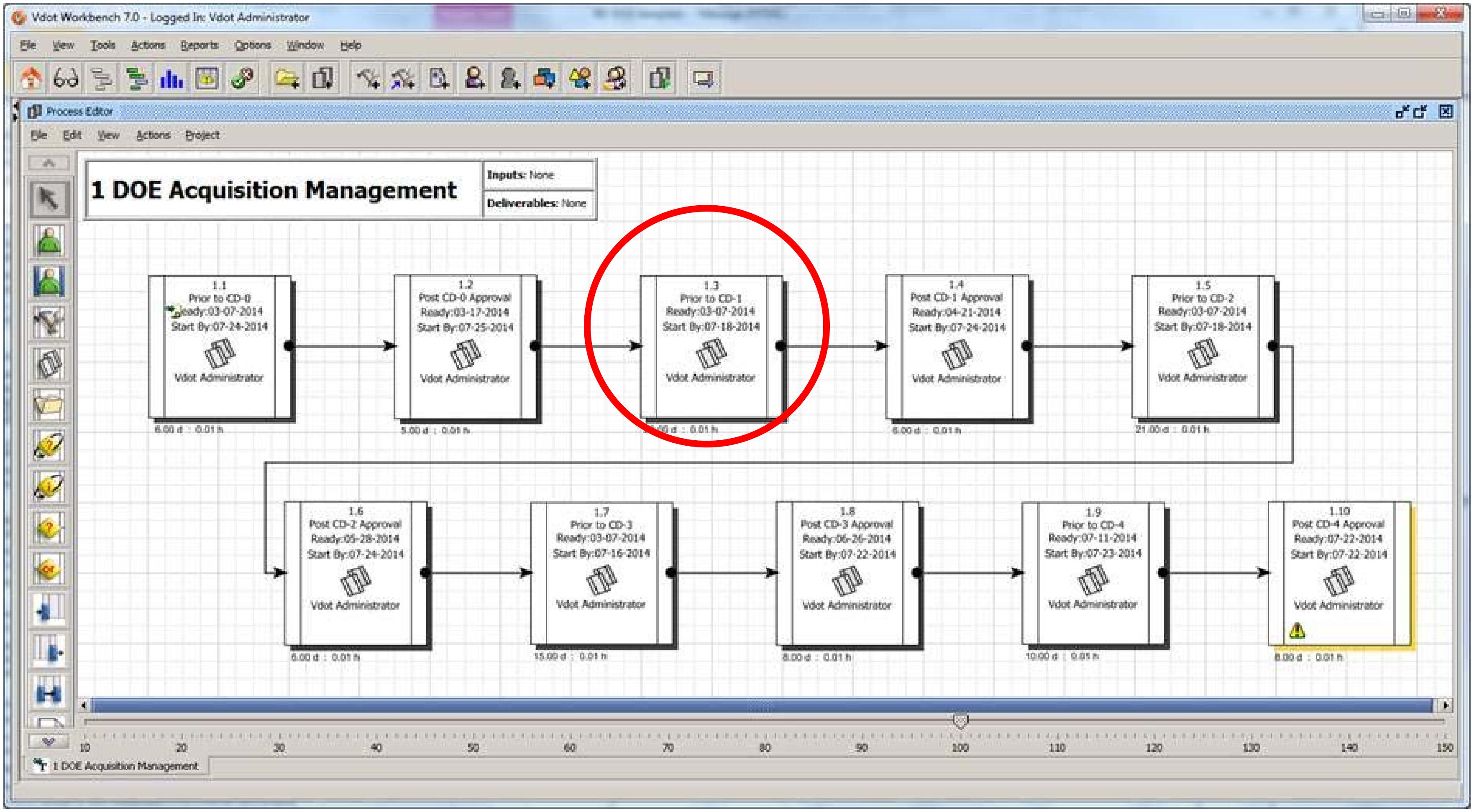

Figure 15. DOE Acquisition Management Systems Engineering Process Modeled in Vdot

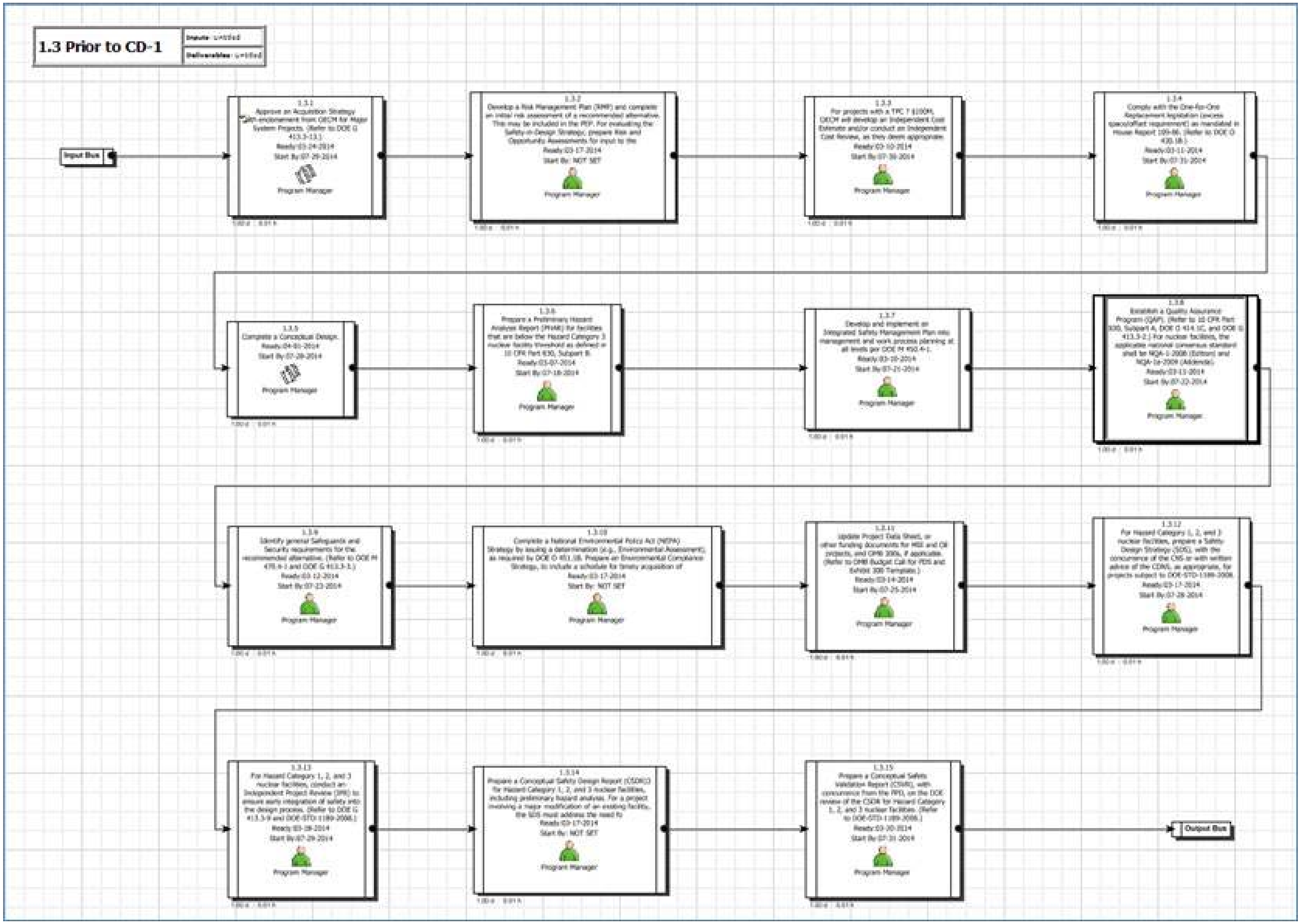

Figure 16. Expansion of Nested Vdot Process Template for "Prior to CD-1"

Appendix A – Energy Huntsville Vision Pamphlet

CONCLUSION

In systems engineering, for a new product project, we have two things to manage: the creation and flow of information, and the resources required to create the information. We used to use disparate systems to manage these two entities. There are now a variety of software systems that allow a more integrated approach to information flow and resource management. We have found great advantage to using these more integrated systems.

By considering information flows during planning, we are able to develop better plans. By being connected to the work through a workflow feature, we can help teammates follow the plan, doing the right task at the right time with the right data. By having the workflow connected to the project management, we have more accurate status information with less effort. By visibly following better plans, we are able to execute our project better, leading to better products.

ACKNOWLEDGEMENTS

The author would like to acknowledge Damian Yañez (with ESI Group North America) for his mapping of the DOE Acquisition Management Systems Engineering process in Vdot, Linda Hudgins (Qualis Corporation) for her mapping of the ETO processes in the Vdot software platform, and Sue DeLary (Qualis Corporation) for her thorough job of editing. Also, the author acknowledges the support and collaboration from Sandia's Dr. Jim Pasch, S-CO2 Principal Investigator, and Gary Rochau, Manager, Advanced Nuclear Concepts, and acknowledges the support from Jay Newkirk, Executive Director of Energy Huntsville.

REFERENCES

1) Dean C. Stevens and Dennis E. Stevens, "Taming the Agile Enterprise: Value Stream Mapping for Knowledge Work", A Synaptus White Paper, July 2010

2) Herdy, R. and Yañez, D., "Increasing M&S V&V Efficiency with the Process Management Tool Vdot™", JANNAF-1245, 2010.

3) Herdy, R., O'Neil, D., Sturken, I., Nix, M., and Yañez, D., "Modeling Constellation Virtual Missions Using the Vdot™ Process Management Tool", AIAA-2009-607, 2011.

4) Herdy, R., and Yañez, D., "Understanding and Managing Information Flows", AIAA- 1655336, AIAA Space 2013 Conference and Exhibit.