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Qualis Corporation, recognized for leading efforts in the incorporation of next generation management processes, recently was engaged in an effort to exercise a multiplidisciplinary design optimization project applicable to Space Exploration, Resources and Colonization for the need to demonstrate an approach for meeting the challenges where operations outside the atmosphere and on extraterrestrial surfaces frequently encounter serious and unique challenges. A design optimization tool just now becoming available to industry was chosen for this project. Vdot™ is a process management tool that provides the ability to define, deploy, and execute desktop processes for distributed teams. It was realized that Vdot automated the manual integration process executed as part of the informal systems integration process implemented by the Vehicle Integrated Performance Analysis (VIPA) methodology developed at NASA's Marshall Space Flight Center (MSFC), where Qualis Corporation has a significant presence. A contract was initiated in early 2007 from the University of Alabama in Huntsville (UAH) Modeling and Simulation Center to the Qualis Corporation to study the utility of using Vdot to manage the VIPA processes and demonstrate a tool to enable Lunar Robotics designs.

I. Introduction

The Vehicle Integration and Performance Analysis (VIPA) process developed at NASA's Marshall Space Flight Center (MSFC) adds critical rigor to the analytical integration within a design process, an area where processes are not well defined and are typically performed in an ad-hoc method by the individual discipline engineers. The ultimate goal for VIPA is to parametrically and associatively link the design of a system to the requirements and the analysis, resulting in a design environment that can cascade changes throughout all features when one or more parameters are changed. The process steps needed to execute these changes within VIPA are well understood, but they are not performed automatically. This paper describes a review of a process management tool to automate the VIPA environment.

Vdot™ is a commercial-off-the-shelf (COTS) process management tool developed and marketed by Procelerate Technologies Inc. (since purchased by ESI Group) that provides the ability to define, deploy, and execute desktop processes for distributed teams. Vdot provides the ability to route data, launch tools (IT applications), and provide

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automatic real-time project status. Vdot's capabilities appeared to be particularly well suited to automate the VIPA process, so a tool evaluation and trade study was initiated. The objective for this study was to document best practices, capture the best approach by which tool and methodology synergy could be achieved, and migrate the lessons learned, architecture definition and mission planning support and optimization knowledge toward upcoming design and development activities at NASA.

As a test of the Vdot tool's ability to support distributed teams as well as lean process management (in addition to automating the VIPA methodology), an analysis of a robotic arm within the VIPA methodology was exercised, with the goal of changing one requirement linked to the design modeled in the VIPA environment – that of the gravitational environment – where changing this value from 1G to 0.6G would initiate the design for a Lunar Rover arm. The first step was a schedule developed using Microsoft Project, which was used to populate an initial Vdot template automatically. The Vdot Project Team was composed of engineers with in-depth experience in project management, design analysis, kinematics, structural, mechanical, and design integration.

The Project Team found that the VIPA process was clearly defined via the programming of the associated inputs and outputs for each integration task within Vdot. And once the Rover Project was activated within Vdot, automated task notifications were very helpful in keeping work flowing through the pipeline—Vdot handled all of the data and task notifications required to keep the development effort running efficiently. In addition, all project statistics were updated automatically thus providing real-time status at any point in the project timeline.

II. Overview

Vdot™ is a process management tool that provides the ability to define, deploy, and execute desktop processes for distributed teams. While attending a demonstration of Procelerate's Vdot Project Management tool, it was realized that Vdot could automate the manual integration process executed as part of the Vehicle Integrated Performance Analysis (VIPA) methodology developed at NASA's Marshall Space Flight Center (MSFC). A contract was initiated in early 2007 from the University of Alabama in Huntsville (UAH) Center for Modeling, Simulation and Analysis (CMSA) to the Qualis Corporation to study the utility of using Vdot to manage the VIPA processes.

As an opportunity to leverage work being performed on the Robotics Systems Joint Project Office (RSJPO) contract and to benefit NASA and upcoming robotics requirements on the Constellation Program, a tool evaluation and trade study was initiated. This evaluation activity exercised VIPA and Vdot, which have potential synergy to address elements of Systems Analysis tasks in the conduct of the RSJPO contract.

Vdot is a commercial-off-the-shelf (COTS) tool developed and marketed by Procelerate Technologies Inc. The evaluation of Vdot took into consideration systems analysis requirements of the RSJPO, the degree of Vdot and VIPA synergy, and an overall strong emphasis on architecture definition support, optimization and mission planning support.

The objective for this study was to document best practices, capture the best approach by which tool and methodology synergy can be achieved, and migrate the lessons learned, architecture definition and mission planning support and optimization knowledge toward upcoming design and development activities at MSFC.

A. Description of Procelerate's Vdot Process Management Tool

Vdot provides the ability to route data, launch tools (IT applications), and provide automatic real-time project status. Project teams should experience reduced data chase, rework, and status reporting effort while enabling greater project and process visibility.

Table 1 Management Challenges and Vdot Features

Program Management Challenge	Relevant Vdot Feature
Schedule overruns	More time to the team for value-added work. Initial schedule based on work to be performed. Schedule projections based on accurate view of work performed.
Not enough staff	More output from teams (critical path knowledge, less data chase/rework, less status reporting). Predicts resource requirements based on detailed task flows.
Unclear status	Real-time project status automatically tied to task deliverables.
Automated systems that cannot handle unanticipated scenarios	Granular task and data item recall capability Unmatched flexibility to modify active processes.
Difficult to understand impact of plan changes	Schedule and resource changes based on detailed task changes
Difficult to implement plan changes	Team dashboards and individual task lists updated automatically. Data routing per plan changes
Time spent discovering problems	Real-time project status automatically tied to work deliverables.

Additional information on Vdot capabilities is available on the Procelerate website:

http://www.procelerate.com/

B. Description of VIPA Methodology

The role of the VIPA team at MSFC can be understood by examining the T-model of systems engineering shown in Figure 1. The legs of the model are the individual engineering disciplines, which have a long history and are well defined in their functions and methods. The top of the block is the formal control of systems engineering including requirements, resource management and project integration. These functions also have a long history and are well defined. The lower part of the block, which can be called Analytical Integration, is an area in which processes are not well defined and is typically performed in an ad-hoc method by the individual discipline engineers involved in the project. VIPA adds rigor to this area by having the discipline leads focus heavily on the system interactions. VIPA penetration down each leg is driven only as deep as necessary for the system analysis. Full, detailed discipline analysis is still performed, but only when needed to support the system team.[4]

The ultimate goal for VIPA is to parametrically and associatively link the design of a system (usually in a 3D solid model via Parametric Technology Corporations (PTC) Computer Aided Design (CAD) package Pro/E) to the requirements and the analysis, resulting in a design environment that can cascade changes throughout all features when one or more parameters are changed. While these changes are not performed automatically, the process steps needed to execute these changes within VIPA are well understood.

[4] Paper, "Managed Development Environment Successes for MSFC's VIPA Team", Authored by: Jeff Finckenor/NASA/MSFC, Gary Corder/Jacobs-Sverdrup, James Owens/Qualis, Jim Meehan/NASA/MSFC, Paul H. Tidwell II, Ph.D. /Allied Aerospace

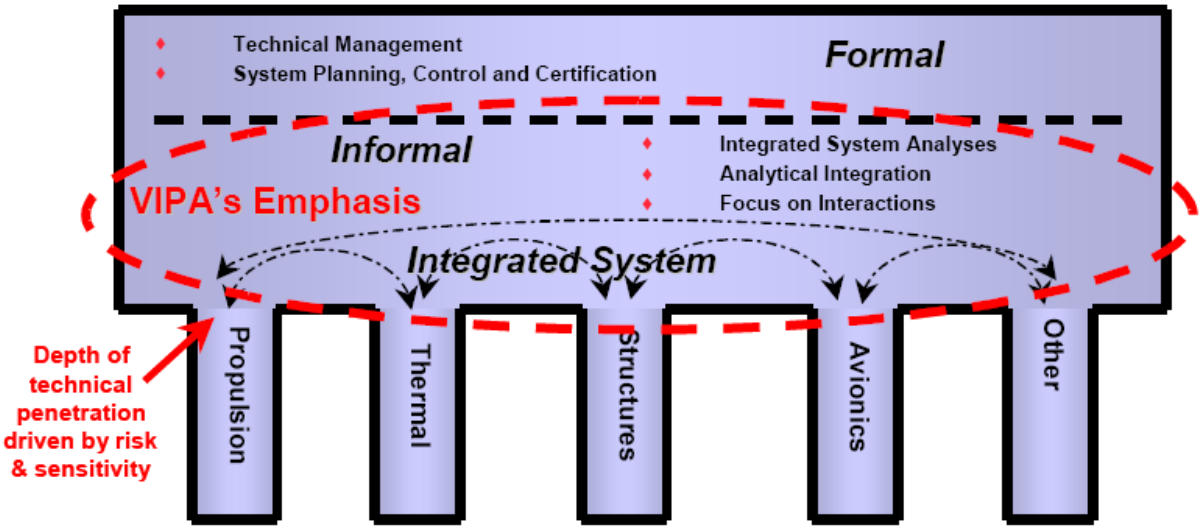


Figure 1. T-Model of Systems Engineering

C. Using Vdot to Manage the VIPA Methodology

As a test of the Vdot tool's ability to support distributed teams as well as lean process management (in addition to automating the VIPA methodology), the Vdot Project Team developed a project model similar to a model that would be developed to support the VIPA methodology during the development process. A schedule was developed using Microsoft Project, which was used to populate an initial Vdot template automatically. A copy of the VIPA development model and the initial project schedule are included in the Backup Section of this report. The real test of the tool would be to automate the very manual VIPA integration process. This approach is depicted below in Figure 2. Documenting the effectiveness of Vdot management software to maximize the efficiency of the VIPA approach is the purpose of this report.

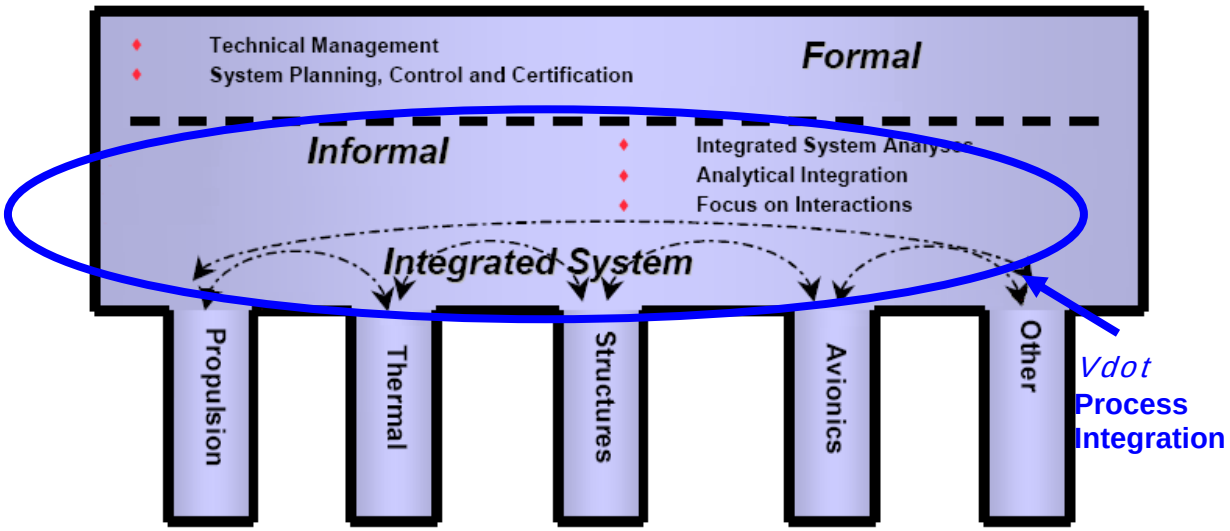


Figure 2. T-Model of Systems Engineering and Vdot Process Integration

III. Rover Project Execution using Vdot and VIPA

A. Description of the Rover Project

The development project effort for the Vdot evaluation activity leveraged existing activities and available subject matter expertise to obtain the greatest synergy possible for this task. For example, Qualis Corporation has an existing contract to support the Robotics Systems Joint Project Office (RSJPO) at Redstone Arsenal. Interfacing with RSJPO provided the robotic systems needed to reverse engineer an existing robotic arm in order to develop the engineering drawings used in the Rover Project. The idea was to use the robotic designs as a "Rover Project" to model potential designs for lunar robotics applications, such as a lunar rover. Automating the linking of the requirements to the analysis and the design via a VIPA environment was the overarching challenge presented to Vdot in this evaluation. Vdot was anticipated to better outline and institute rigor for morphing the design from a terrestrial rover to a lunar rover by automating the changing of requirements (for example, the local gravity in which the rover needs to operate).

The Rover Project activity began by obtaining actual hardware from a TALON™ robot (see Figure 3), specifically the robotic arm. CAD engineers disassembled the robotic arm, measured, and weighed each part. Next, they provided obtained measurements to a requirements engineer who documented those measurements (along with additional specification information developed by the TALON™ robot vendor, Foster-Miller, and located on the vendor's website[5]) as an initial set of "rover" requirements. Thus, Design Analysis Cycle 1 (DAC-1) was initiated and mapped within the Vdot environment.

Figure 3. TALON™ Robot

The Project Team reviewed and provided comments on the "Rover Requirements Document". Once all comments were reviewed and approved, the "Rover Requirements Document" was updated and base lined and made available to the Project Team for the rover design activity. These requirements became the inputs to the CAD, kinematic and structural model design activities. All of the coordination and information exchange was performed within the virtual environment of Vdot.

After the initial version of the rover design was completed, designers conducted a review to evaluate all design work, and determine any additional updates needed to validate the rover "master model" and complete DAC-1. DAC-2 was an abbreviated iteration of DAC-1, starting with a minor requirements update. The team determined

[5] Brochure, "The Soldier's Choice TALON™ robots", Foster-Miller, A QinetiQ company, http://www.foster-miller.com/literature/documents/TALONBrochure.pdf

that to decrease the rover arm's range of motion, decrease the rover arm's length and to account for lunar gravity would be enough of a requirement update to accommodate the change from a terrestrial rover to a lunar rover (for the purpose of demonstration only).

The Project Team reviewed and provided comments on the "Lunar Rover Requirements Document", the requirements were then updated and baselined, and again the requirements became the inputs to the CAD, kinematics and structural model design activities. Because the initial model work had already been mapped and exercised within Vdot with updates made as required while the work was completed, design work to update the model with new requirements was minimal. When the lunar model was complete, designers conducted a review to evaluate all design work, determine any additional updates needed to validate the lunar rover "master model" and complete DAC-2. Again, this was done with the aid of the Vdot tool, and one very apparent benefit was that all work process steps could be conducted remotely over the internet and/or within the UAH Local Area Network (LAN).

B. Description of the Hardware and Software Environment

One can see from Figure 4 the relatively simple configuration of the complete system. Our test system utilized two large desktop machines and supported users internally and remotely. The hardware was less than the recommended configuration[6]; however the system performed flawlessly for the test group. (See Appendix A for more information on hardware and software installation recommendations.)

Two servers each performed two functions. The server labeled Alpha performed both licensing functions (authentication), verification of Vdot resource availability, and hosted the Web Application. The server labeled Bravo performed as the file resource server and database management (metadata). Both machines supported COTS operating systems and COTS applications.

System Operate & Maintain functions were less than expected once the system setup was completed. Setup and certain configuration management tasks were managed directly on the server while daily system use occurred either at the desktop via the Vdot Workbench application (for intense system manipulation) or via the HTTP interface (for lighter management tasks).

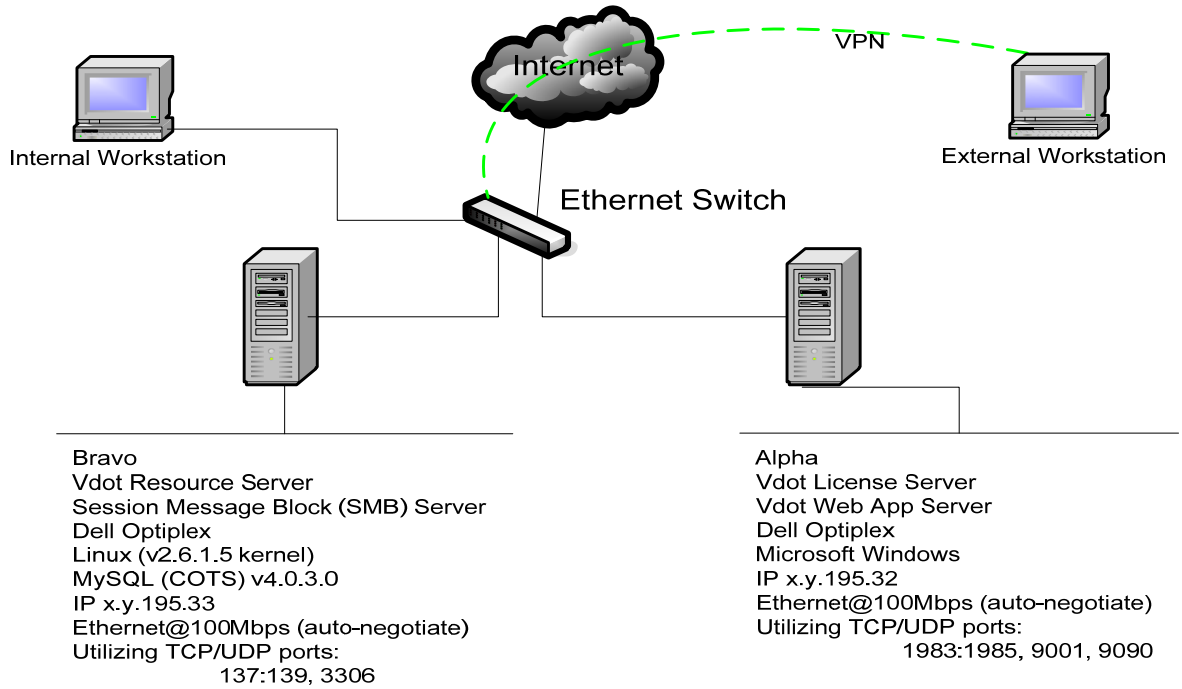


Figure 4. System Configuration for Vdot Evaluation

[6] Document, PTI-VDOT-0033 Hardware and Software Requirements Document, Copyright © 2006 Procelerate Technologies Inc.

An Information Technology engineer assigned to over see the operations, architecture and engineering in large, complex enterprise environments noted the importance of the ease of installation and operation, and indicated this was one of the most powerful systems he had witnessed operating on minimum hardware and support. The system worked well for users on the same campus network or remotely over VPN sessions. It is believed the similar configurations would lend an easy implementation to most networks.

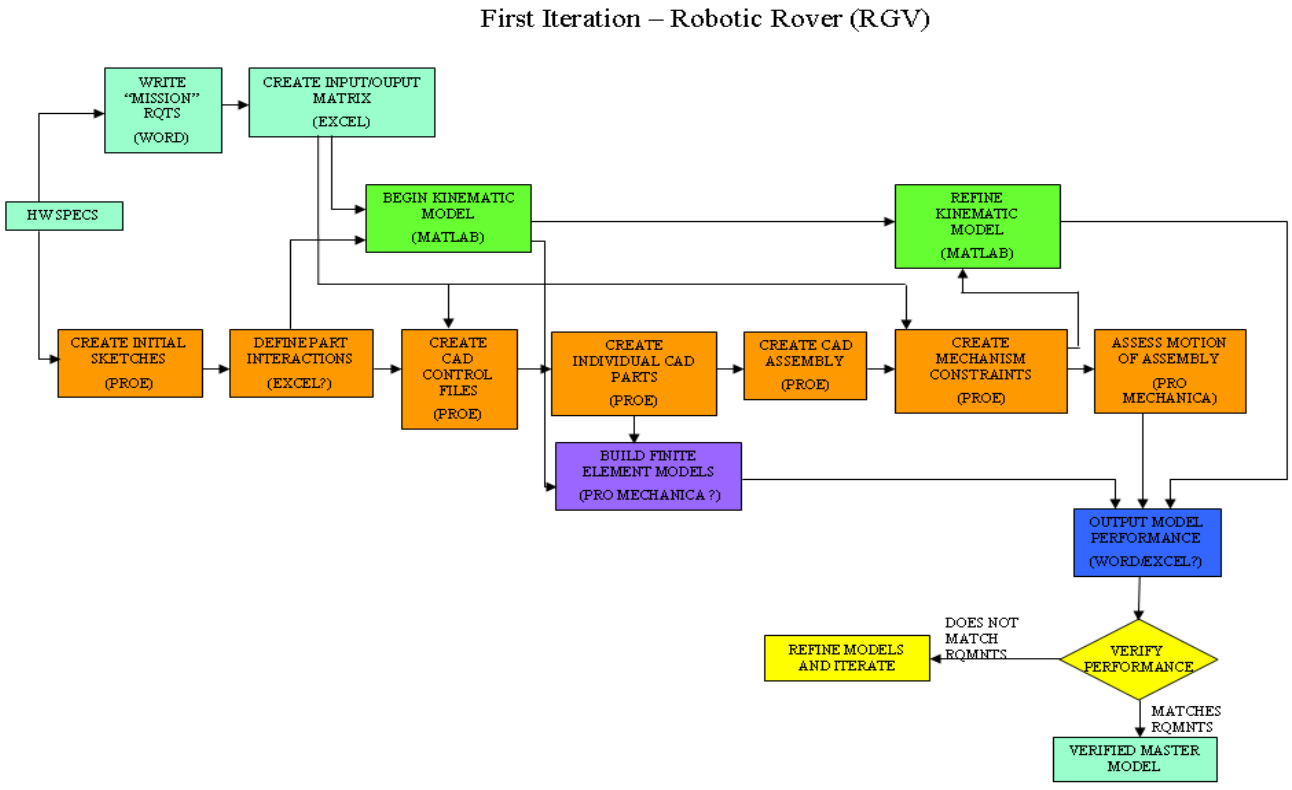
C. Project Execution

The Vdot Project Team was composed of engineers with in-depth experience in project management, design analysis, kinematics, structural, mechanical, and design integration. In addition, members of this team also had experience with a wide range of engineering and project management tools and methodologies, including PTC's Pro/Engineer (Pro/E), Mathwork's MATLAB®, NASA STRuctural ANalysis (NASTRAN), PTC's Windchill, Microsoft Project, Vehicle Integrated Performance Analysis (VIPA), and Preliminary Analysis of Revolutionary Space Exploration Concepts (PARSEC).

D. Role of VIPA in Requirements and Design Analysis Phase

The Project Team found that the process of defining the informal integration between engineering disciplines, and programming the inputs and outputs for each task within Vdot was very beneficial for the launching of the Project. The process helped them better understand "what" data was needed "when", its required format, and who would be providing the data.

After development of the VIPA model for the Rover Project (see Figure 5) and the initial project schedule, the development team met at UAH for one day of training. Procelerate provided an experienced trainer to educate the team in setup and use of the Vdot tool and to answer questions specific to the development project.



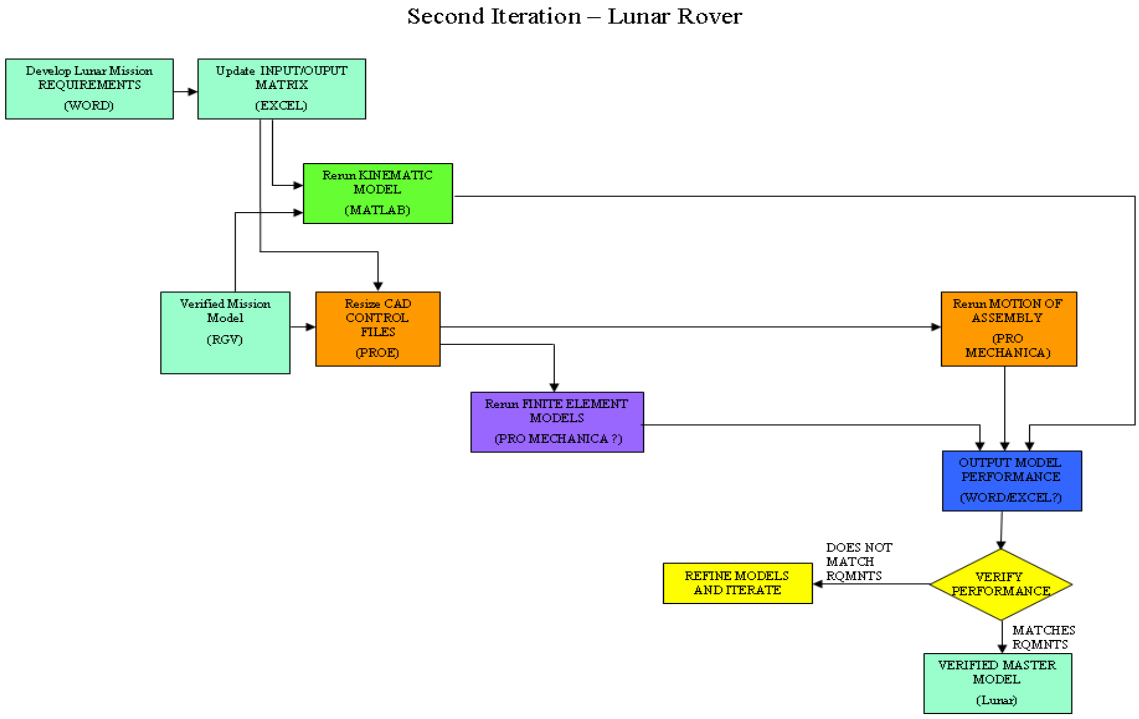


Figure 5. Initial VIPA Model

After training was completed, the team worked with the trainer to upload the initial project schedule by importing the Microsoft Project schedule directly into Vdot. By importing the project schedule, an initial project template was created by Vdot. The team refined the template, ensuring that each task had appropriate inputs and outputs defined, named resources allocated, and appropriate schedule dates. When the project template was complete, an updated Microsoft Project schedule was exported from the tool. This schedule is included in the backup section of this report. Once this effort was accomplished, the team was able to activate the Rover Project within the Vdot tool by changing the gravitational constant requirement, which initiated a Lunar Robot arm design.

E. Using Vdot to Manage the Rover Project with Real-time Status

Once the Rover Project was activated within Vdot, team members began receiving email notifications from the tool. When an engineer received an email "work notice", they would log on to Vdot and start working their assigned tasks. Once logged on, team members could initiate their engineering applications (such as Pro/E) using updated data files provided automatically by the outputs of the previous task. After performing their tasks, team members could upload their updated working files into Vdot and mark their tasks as complete. When assigned tasks were marked "Complete", Vdot would send an immediate email notice to the next process owner notifying them that their task was ready to be worked and that their data files were available.

Automated task notifications were very helpful in keeping work flowing through the 'pipeline' so that team members were not required to figure out who needed their output files next. Vdot handled all of the data and task notifications required to keep the development effort running efficiently. In addition, when engineers would access Vdot to mark their tasks "started" or "completed", all project statistics were updated automatically, thus providing real-time status at any point in the project timeline.

One of the most helpful features of Vdot was the task listing, showing percent complete and any tasks that were behind schedule. At a glance, the Project Lead could quickly determine where a schedule "hold-up" was occurring, as well as which team member was responsible. With one phone call, the Project Lead could find out if there was a task problem that needed to be worked or if a team member just needed to be reminded they should get started on their next task. The ability to view a real time, true critical path was clearly a superior feature over other project management tools such as MS Project.

Another extremely helpful feature of the Vdot tool is the graphical representation of the project workflow – in progress. For example, in Figure 6 below it is very clear that the "2.3 Develop LR CAD Model" task is "In Work" and that the "2.4 LR Finite Element Models" task has not yet been started, and is behind schedule.

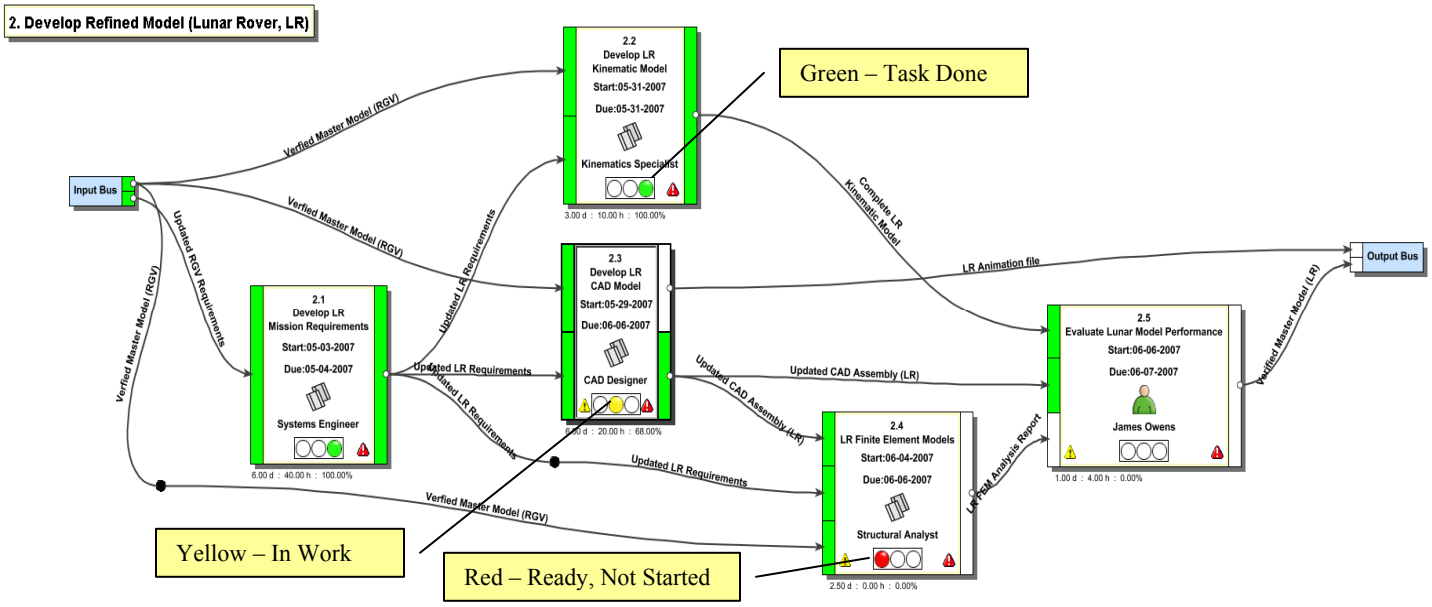


Figure 6. Vdot Process View Showing Real-time Status

By 'double-clicking' on the "2.3 Develop LR CAD Model" task (see Figure 7), the Project Lead can drill down and see that the "2.3.3 Create Visualization" task is the only task needed to complete that portion of the project, and that task is "In Work". The Project Lead can also see that the "2.3.3 Create Visualization" task is late (red triangle), but is not on the critical path (yellow triangle).

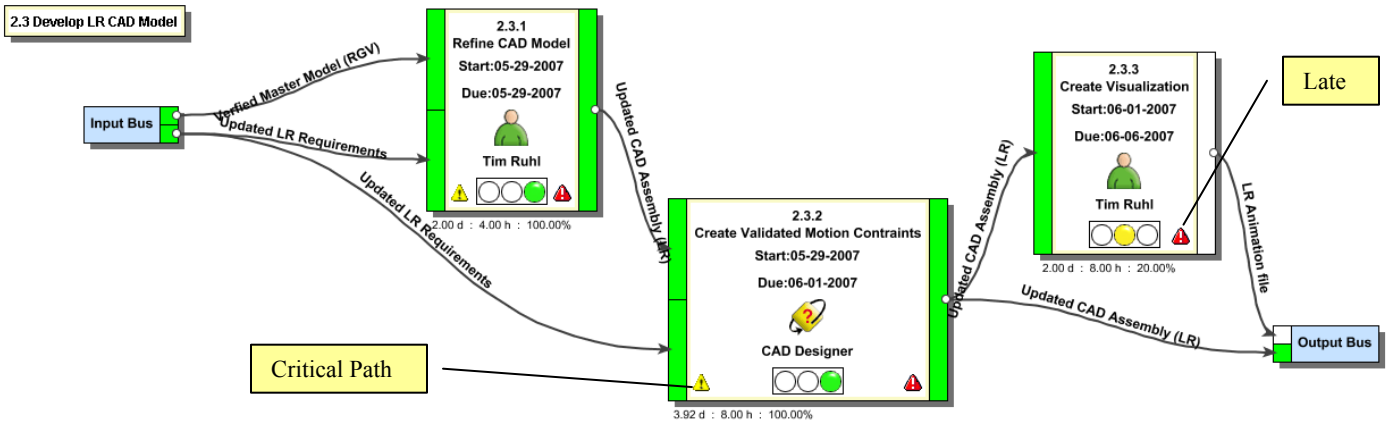


Figure 7. Late Tasks and Critical Path in Vdot Subprocess

Now the Project Lead knows that it may be more productive to first focus on what is going on with the "2.4 LR Finite Element Models" task which has not yet been started, than with the "2.3.3 Create Visualization" task.

IV. Vdot Integration

A. Vdot and the PTC Windchill Environment

Parametric Technology Corporation's (PTC) Windchill ProjectLink is a project management tool available to all Exploration Systems Mission Directorate (ESMD) projects. Windchill provides project management capabilities that include:

- Workflow and data routing
- Document management, including bulk upload/download
- Definition and management of milestones, tasks, deliverables and resources
- Status reporting
- Web access
- User-configured subscription and notification capabilities

At MSFC, Windchill is primarily used as a document management tool. Even in cases where the data routing capability is used by Configuration and Data Management (CDM) personnel in the implementation of the Change Request evaluation process, data routing is still in place as a support tool for document management. Windchill workflow and data routing capabilities are not used for work collaboration purposes. In addition, MSFC does not take advantage of Windchill's milestone, task, action item, deliverables and resource tracking capabilities.

Being that MSFC does not use PTC Windchill ProjectLink as a project management tool; a detailed comparison of the capabilities of each tool was not performed. However, it should be noted that Vdot provides all of the project management capabilities (as noted above) that PTC Windchill provides, and Vdot provides such features graphically. This study has investigated the use of Vdot within the Windchill environment, primarily as an application available from pull-down menus on the Integrated Collaborative Environment (ICE) Portal. There are several applications already available to ESMD users via the ICE Portal, including Active Risk Manager (ARM), Cradle, Integrated Risk Management Application (IRMA), Primavera and several others. Vdot project management features are compatible within the Windchill environment, and upon approval, could be included on the list of ICE Portal applications.

B. Using Vdot in Conjunction with Microsoft Project

Microsoft Project is a project schedule tool widely used at MSFC. Microsoft Project provides limited project management capabilities that include:

- Definition and management of milestones, tasks, deliverables and resources;
- Schedule and resource status reporting.

When initially configuring and setting up Vdot to support the robot development project, the original project schedule was imported into Vdot and then automatically converted into a process flow. The process flow was then fully defined by adding information flows and the applications acting on that information. When adding the information flows, tasks were discovered that produced data needed by no one and/or that required data from undefined tasks.

After the Project Team completed configuring and inputting project processes and data flows into Vdot, an updated Microsoft Project schedule was exported from the Vdot tool. The updated schedule reflected the basic structure of the initial schedule, but included far more detail documenting the "hidden" or additional tasks found when configuring Vdot. The updated schedule also contained the updated start/end dates, and personnel assigned to the various tasks.

At various points during the project development cycle, Microsoft Project schedules were exported from Vdot and used as additional checkpoints and reporting mechanisms. Team members determined that the exported project schedules had all required information, and were able to be updated and manipulated just as any other schedule initially developed using the Microsoft Project scheduling tool. This feature allows projects using Vdot to provide Microsoft Project compatible schedules as a reporting mechanism to other organizations, should that capability be required.

A popular book about Microsoft Project includes the line: "It would be nice if people had work-meters attached to them". This would enable automatic progress tracking. A big problem is the effort required to collect the status data. This is a difficult and costly activity which can result in out of date or wrong information. It is impossible to

make timely development decisions based on incorrect or out of date information. Vdot provides virtual work-meters for the computing systems being used by development teams, reducing the costly effort of collecting status information. More importantly, it ensures that critical decisions are made on the basis of the most accurate and up-to-date information.[7]

C. Using Vdot in Conjunction with Engineering Applications

Vdot can be configured as a coordination layer on top of discipline-specific tools (such as NASTRAN or Pro/E). Within the Vdot environment, engineers have the ability to define and execute their discipline-specific tool, then properly route the results using Vdot. All of the discipline-specific tools work with data that is properly structured to work with the particular application. These applications read and write data in their own proprietary formats. In specific cases, Product Lifecycle Management (PLM) and Integration Systems create a meta-structure for CAD or other application data in a back-end database or middleware layer.[7]

This capability was exercised in the Vdot evaluation study, where Vdot was configured to work in conjunction with the Pro/E CAD tool. CAD developers participating in the Vdot evaluation study had the capability to initiate Pro/E from Vdot and develop their CAD models. When their work was completed, they were able to upload the required Pro/E files to Vdot for routing to the next step in the workflow process. This capability was setup and configured within Vdot by the Project Lead in less than ten minutes by someone not at all familiar with the Pro/E tool. This capability alone is a testament to the intuitive navigation and ease of integration features provided by Vdot.

D. Using Vdot in Conjunction with PARSEC

Currently, Preliminary Analysis of Revolutionary Space Exploration Concepts (PARSEC) is solely being used as a database from which analysts can import, export, and store data. Each discipline has its own tool and a "workspace" containing widgets. Analysts link portions of their tools' input and output files to the individual widgets and then the appropriate data populates the widgets after the tool is executed. Then the data is exported to the database so the next analyst can pull in the individual values and run his tool.

Vdot has the ability to pass along entire input/export files but out of the box it cannot grab a certain cell from Excel or a line item from a text file without using an add-on such as Procelerate's OfficeManager™ or writing a specific macro to do so. Vdot could, however, be the overarching project management tool for a study in which PARSEC was used.

In an example, a NASA study lead or contractor design team coordinator would set up the various tasks that would need to be done for a given project (plus schedule, resources, etc.). For the sake of this example, let's say a mass breakout of a Lunar Lander descent stage was the product. Each discipline lead would be responsible for using PARSEC to run their analysis when the appropriate data was available to them. After the PARSEC analysis was finished, an analyst could upload the entire Excel file that had the mass breakout into Vdot, which would then forward the data to the study lead. And during the course of the activity, the NASA study lead could check Vdot to see where in the design process the analysis team was as well as determine if the team was running propulsion, thermal or structures analyses at that time.

[7] Paper, "Vdot™: Relationships to Other Technologies", Copyright © 2005 Procelerate Technologies Inc.

V. Discussion of Vdot Attributes

A. Evaluation Results of the Vdot Tool

Midway through the study, evaluation criteria were developed and reviewed within the Project Team. These criteria were documented in a spreadsheet and distributed to the entire team to capture all team perceptions and input as they exercised and reviewed various features of Vdot. Scoring was captured using a scale of 1-5, where 1 = Does Not Meet Requirement and 5 = Exceeds Requirements. A score of 0 = Not Applicable. The detailed results are contained in Appendix B of this report.

B. Overall Score - Entire Team Results

A summary of the results collected from the entire Project Team has been captured in Table 2 below.

Table 2 Overall Score – Entire Team

Category	Overall Score
Project Scheduling and Management	4.07
Resource Management (Allocation and Work Effort Tracking)	3.94
Team Communication and Collaboration	3.74
Project Dashboard and Reporting	3.83
User Interface and Ease of Use	4.13

In addition to scoring the tool, comments (positive and negative) were solicited from the Project Team. A subset of those comments (duplications removed) are captured in Table 3 below. A detailed list of all comments is also included in Appendix B of this report, along with Procelerate's responses. The quick resolution of many of the negative findings revealed in the Procelerate list highlights an additional strength of Vdot – a responsive development team.

Table 3 Overall Comments

Positive Comments	
1.	It's very nice to have a quick look at who owes you what so you can get started with a task, and conversely to whom you owe output.
2.	It's also VERY HANDY to have all the input data you need RIGHT ON THE PAGE with your task.
3.	Good way to view overall task workflow
4.	Could be very powerful tool for simple processes
5.	Quick access to requirements and project documentation
6.	Takes the Program Management effort to a new level, one that offers time saving options.
Negative Comments	
1.	Unless a document (file) was directly tagged as an input to your task, there appears to be no way to access it. (Admittedly I missed most of the training, so maybe you can access other documents. But if so, it was not easy to find out how.) [This feature is available through the Workbench. It is also be added to VdotWeb for the next release.]
2.	Not able to easily add more documentation beyond what was originally requested for task. Not able to add documentation in format other than that which is requested for task (e. g. Word file instead of Excel when tasked with Excel format) – not even with Sys Admin privilege – unless the task was rolled-back. [Using Multi-file types for the data allows attachment of any number of files. Procelerate is also adding the ability to add inputs and outputs to in-work tasks based upon this feed back.]
3.	Problems with the IT issues - Web access was not always available (side effect of using web access for anything) [Delays in setting up UAH server access have been resolved.]
4.	Might be more useful for structured analyses that are repetitive in nature, but not good for case-by-case analyses that must be initiated to realize what is required for the task
Suggestions for Improvements in Upcoming Releases	

1.	Would really like to see an automated messaging (email) to specific users incorporated to help with ability to communicate with Project Team members. [Procelerate has already added this feature since the study.]
2.	Would like to be able to access predecessor documents that fed into the input for a task assigned to me. Other documents might be nice to. I can understand limiting this access as a security feature, but it seems that at least those predecessor documents should be available to tasks downstream. [This feature is available through the Workbench. It is also being added to VdotWeb for the next release.]

C. Overall Score – Project Leads and Managers Results

In the evaluation results included above, each team member's input was given equal weight (i.e., end users inputs were given the same consideration as inputs from Project Leads and Managers). If only the opinions of the Project Leads and Managers were considered, the Overall Score averages would be as follows in Table 4 below.

Table 4 Overall Score – Project Leads and Managers

Category	Overall Score
Project Scheduling and Management	4.41
Resource Management (Allocation and Work Effort Tracking)	4.48
Team Communication and Collaboration	4.50
Project Dashboard and Reporting	4.06
User Interface and Ease of Use	4.50

As can be seen, the Overall Score is extremely favorable towards Vdot as a valuable tool for managers and leads. It supports management's ability to quickly assess problem areas and greatly reduces the uncertainty of who is directly responsible for work accomplished at any point in the project life cycle. Vdot was invaluable in managing a development project with a very distributed engineering team, spread across several disciplines and development tools. Vdot can be configured to fit seamlessly into the MSFC development environment. The Team agreed that Vdot should be strongly considered for managing future programs and on-going development activities at MSFC and elsewhere at NASA.

VI. Follow-on Potential

A. Recommendations for Future Work

There are many opportunities within MSFC to utilize Vdot as a project management tool. The Vdot evaluation study team is recommending a project or task with the following characteristics, to be considered as a pilot project to implement Vdot into the NASA development environment.
Recommended characteristics for a Vdot Pilot Project include:

- Approximately 10 FTEs
- Use of discipline-specific tools (Pro/E, NASTRAN, etc.)
- Interfaces with at least three different disciplines/organizations (mechanical, structural, thermal, etc.)
- Defined deliverables (format, schedule)

There are currently two open Task Description Sheets (TDSs), CLV-28-1001 and CLV-28-1002 that would be possible candidates for piloting Vdot. While the work for these TDSs has already been initiated, both of these tasks have deliverables required for the CLV System Definition Review (SDR) and the Preliminary Design Review (PDR). It may be possible to use the time prior to SDR (scheduled for September 2007) to setup and configure Vdot in preparation to manage post-SDR efforts and to support PDR.

Waiting until after SDR to initiate activation of Vdot still allows time (from now until SDR) to bring Vdot into the engineering environment, configure the tool, and train personnel. As soon as SDR is completed, the next phase of development for these TDSs could be tracked and managed using Vdot. The advantage of waiting until SDR to activate use of Vdot will ensure defined milestones and deliverables (at task start and finish) to provide measurable results and metrics from its use.

VII. Appendix A – Vdot System Installation Requirements[4]

A. Vdot Workbench

The Vdot Workbench is a client application that is installed on each end user's machine. The Vdot Workbench should have access to a Vdot Resource Node and, if applicable, a Vdot License Server.

- Supported Operating Systems
  - Windows 2000 Professional
  - Windows XP Professional
- Memory
  - 512 MB RAM minimum
  - 1 GB RAM preferred
- Processor
  - 1 GHz CPU minimum
  - 2 GHz CPU preferred
- Hard Drive
  - 500 MB free disk space, 7200 RPM
  - 1 GB free disk space, 10000 RPM
- Network Card
  - 100 MB Ethernet minimum, static host name
  - 1 GB Ethernet preferred, static host name

It may be necessary for the Vdot Workbench to communicate with other Vdot components (i.e. License Server, Resource Node, etc.). Accordingly, a suitable network topology may be required. Vdot e-mail notifications can be sent by the Vdot Workbench to other users. If Vdot messaging will be used, ensure that a SMTP server is accessible.

B. Vdot License Manager

The Vdot License Manager serves licenses on-demand based on an established, flexible license agreement, facilitating and expediting transparent, enterprise-wide license distribution.

- Supported Operating Systems
  - Windows 2000 or 2003 Professional, Server
  - Windows NT 4 Server
- Memory
  - 512 MB RAM minimum
  - 1 GB RAM preferred
- Processor
  - 1 GHz CPU minimum
  - 2 GHz CPU preferred
- Hard Drive
  - 250 MB free disk space minimum, 7200 RPM
  - 500 MB free disk space preferred, 10000 RPM
- Network Card
  - 100 MB Ethernet minimum, static host name
  - 1 GB Ethernet preferred, static host name

The Vdot License Manager may be installed on the same machine as a Vdot Resource Node. Four TCP/UDP ports will need to be available to ensure users can obtain Vdot licenses. These are ports 9001, 1983, 1984, and 1985.

C. Vdot Resource Node

The Vdot Resource Node consists of a database and a shared file system. Both components can be located on the same machine or on separate machines. The Vdot Resource Node machine(s) should be near machines running the Vdot Workbench in terms of logical network location to ensure maximum throughput and minimal latency.

- Supported Operating Systems
  - Windows 2000 or 2003 Professional, Server
  - Linux x86 Red Hat
  - Others upon request
- Memory
  - 2 GB RAM minimum
  - 4 GB RAM preferred
- Processor
  - 2 GHz CPU minimum
  - Dual 2 GHz CPU preferred
- Hard Drive
  - 1 GB free disk space minimum, 7200 RPM
  - 5 GB free disk space preferred, 10000 RPM
- Network Card
  - 100 MB Ethernet minimum, static host name
  - 1 GB Ethernet preferred, static host name
- Network File System
  - Network File System (NFS)
  - SMB
  - Samba

If Vdot will be used in a heterogeneous file operating system environment, ensure that each machine is able to communicate with the target file system. For example, in a UNIX and Windows operating environment, if the shared file system is on a UNIX machine, verify that the Windows machines can access the shared UNIX file system. Database and file server ports must be available to the appropriate users' services to allow Vdot access to relevant user files and system metadata.

D. Vdot Web Application Server

Vdot Web provides a web-based interface to most of the capability contained within the Vdot Workbench application.

- Supported Operating Systems
  - Windows 2000 or 2003 Professional, Server
  - Linux x86 RedHat
  - Others upon request
- Memory
  - 2 GB RAM minimum
  - 4 GB RAM preferred
- Processor
  - 2 GHz CPU minimum
  - Dual 2 GHz CPU preferred
- Hard Drive
  - 1 GB free disk space minimum, 7200 RPM
  - 5 GB free disk space preferred, 10000 RPM
- Network Card
  - 100 MB Ethernet minimum, static host name
  - 1 GB Ethernet preferred, static host name

The Vdot Web Application Server may be installed on the same machine as a Vdot Resource Node. A specific Java Application Development Environment (J2SDK) will be installed and configured. A few ports may need to be available to ensure users can access Vdot Web. For our project, the application was configured to utilize web traffic on port 9090 (i.e. customizable).

E. Additional Notes on Vdot Setup

Vdot component requirements may vary depending on peak usage and machine load. Minor modifications to firewall settings or restricted network traffic configurations may be required to enable requisite machine communications. For customers with less than 10 seats, the Vdot Resource Node can be hosted on an end user's workstation if the machine meets the hardware requirements for the Resource Node as recommended in Appendix A.3. Please refer to Figure 3 to view the system as implemented for the study.

VIII. Conclusion

The Project Team demonstrated that Vdot is a valuable tool for managers and leads exercising the VIPA process. It supports management's ability to quickly assess problem areas and greatly reduces the uncertainty of who is directly responsible for work accomplished at any point in the project life cycle. Vdot was invaluable in managing a development project with a very distributed engineering team, spread across several disciplines and development tools. Vdot should be strongly considered for managing future simulation based designs within the VIPA environment at MSFC and elsewhere at NASA.

Vdot was deemed to be a superior next generation process management tool and greatly increased the flow of activities associated with the MSFC VIPA environment. The goal of using the design of a RSJPO ground robot to demonstrate the utility of VIPA project managed via Vdot to enable a quick and accurate Lunar Robot arm design with the change of the single requirement of the gravitational value was successfully demonstrated.

IX. Appendix B Supporting Materials

A. Evaluation Checklist

All Vdot development team members were requested to provide inputs to the Evaluation Checklist. Detailed results from these inputs are documented below.

			Individual Respondents								
1	**Project Scheduling and Management**		A	B	C	D	E	F	G	# Responding	Avg
	1	Provides useful charting (e.g. Gantt, Dashboards) for determing project schedules	5	4	5	5	5	5	5	7	4.86
	2	Ability to drill-down into each activity or step	5	5	3	5	5	5	5	7	4.71
	3	Ability to compare actual versus forecast comparisons on project scope and time			4	5		5	3	4	4.25
	4	Ability to design multi-level task hierarchy (i.e. high-level activities and sub steps)	5	4	4	3	5	4	5	7	4.29
	5	Ability to track percent completion of individual tasks	5	4	5	5	5	3	4	7	4.43
	6	Slack path analysis (i.e. easy to identify steps which are non-critical)	5	4	3	2	4	4	5	7	3.86
	7	Critical path analysis (i.e. easy to identify steps which are critical)	5	5	3	2	4	4	5	7	4.00
	8	Ability to easily assign, reassign, or cancel tasks	5	3	3	1	5	4	5	7	3.71
	9	Ability to customize project process or status "views"	4		3	3	4	4	5	6	3.83
	10	Ability to compare schedules across projects	3		4	3	3	4	5	6	3.67
	11	Ability to communicate to project teams or stakeholders using tool	2	4			3	3	5	5	3.40
	12	Ability to track projects by type and stakeholder	4				4	5	5	4	4.50
	13	Project templating - create new project plans using completed/succesful projects as a guide or example	4				4		5	3	4.33
	14	Ability to drive accountability and task management to the individual team or task owner level	5	5			4	4	5	5	4.60
	15	Ability to document and incorporate changes to processes even after they are launched	2	4	3		3	4	5	6	3.50
	16	Ability to manage documents as part of the process	2	3	3		3		5	5	3.20
										0	
		Score/Total/Average									4.07
2	**Resource Management (Allocation and Work Effort Tracking)**		A	B	C	D	E	F	G	# Responding	Avg
	1	Ability to forecast individual workload and capacity	4		3	4	3	5	3	6	3.67
	2	Ability to assign tasks to roles and users	5		3	3	4	5	5	6	4.17
	3	Ability for resources to reassign tasks to other team members	5		4	3	4	5	5	6	4.33
	4	Ability to categorize task by "type" (e.g. Maintenance, New Development, Administrative)	4		3		3	4	5	5	3.80
	5	Ability to establish superior - subordinate relationships	4		3		3		5	4	3.75
										0	
										0	
										0	
		Score/Total/Average									3.94
3	**Team Communication & Collaboration**		A	B	C	D	E	F	G	# Responding	Avg
	1	Automatic notification when tasks are teady	5	5	5	5	3	4	5	7	4.57
	2	Automatic notification when data or tasks are recalled	4	5		2	3	4	5	6	3.83
	3	Ability to add notification recipients when an event occurs	4		4	3	3		5	5	3.80
	4	Ability to encourage the usage of Best Practices	4		2		3		5	4	3.50
	5	Document repository capabilities	3	3	2		3	2	5	6	3.00
										0	
										0	
										0	
										0	
		Score/Total/Average									3.74
4	**Project Dashboard & Reporting**		A	B	C	D	E	F	G	# Responding	Avg
	1	Intuitive graphs and charts	4	5	4		4	4	5	6	4.33
	2	Reporting on individual projects or multiple projects	4	4			4	4	5	5	4.20
	3	Comparison of projected to baseline	3	4			3		5	4	3.75
	4	Earned Value metrics	3		3		3		4	4	3.25
	5	Export data capabilities	3		3		3		5	4	3.50
	6	User preferences for filtering and sorting of dashboards	3				3	4	5	4	3.75
	7	Automated projection updates	3			5	3	4	5	5	4.00
	8	Real-time status collection	3	4		4	3	4	5	6	3.83
										0	
		Score/Total/Average									3.83
5	**User Interface and Ease of Use**		A	B	C	D	E	F	G	# Responding	Avg
	1	Overall intuitive design (easy to learn)	5	5	4	5	5	4	5	7	4.71
	2	Appeal of colors (easy on the eyes)	4	5	4	5	4	4	5	7	4.43
	3	Simplicity versus clutter on screen	4	5	3	5	4	5	5	7	4.43
	4	Number of mouse clicks to accomplish common tasks	4	5	2	4	4	4	5	7	4.00
	5	Intuitive navigation for finding features	4	4	2	3	4	3	5	7	3.57
	6	Automatic population of data in fields	3	5	3	3	3	3	5	7	3.57
	7	Logical workflow presentation and process navigation	4	5	5	5	3	4	5	7	4.43
	8	Tool tips and other integrated help functions	4		4	5	3		5	5	4.20
	9	Easy integration of desktop applications	4	4	2	5	3		5	6	3.83
										0	
										0	
		Score/Total/Average									4.13

B. Additional Comments

Additional comments were solicited from Vdot development team members. A detailed list is included below.

Additional Comments

Things I liked about VDOT:
I really like the graphical user interface structure to populate and monitor data.
It's very nice to have a quick look at who owes you what so you can get started with a task, and conversely to whom you owe output. It's also VERY HANDY to have the input data you need RIGHT ON THE PAGE with your task.
Good way to view overall task workflow
Could be very powerful tool for simple processes
Quick access to requirements and project documentation
I thought it was a really great tool that can be used easily in future projects
Takes the Program Management effort to a new level, one that offers time saving options.
Great Project tracking and keeps a great communication & status through the project.
Deadlines are easily visible and keeps you aware of approaching critical paths.

Things I didn't like about VDOT:
Would really like to see an automated messaging (email) to specific users incorporated to help with ability to communicate with project team members.
Unless a document (file) was directly tagged as an input to your task, there appears to be no way to access it. (Admittedly I missed most of the training, so maybe you can access other documents. But if so, it was not easy to find out how.)
Task cannot begin until subsequent tasks are completed
Not able to easily add more documentation beyond what was originally requested for task
Somewhat overloaded with information on first use
Very time consuming setup
Web access was not always available (side effect of using web access for anything)
Not able to add documentation in format other than that which is requested for task (e. g. Word file instead of Excel when tasked with Excel format)
Lose some autonomy and productivity while waiting to be told what is next
Still not convinced of its necessity and or utility to manage project.
Hassle with the IT issues
Not sure if it was the way we had it setup:
Had to attach files for release approval, would have been good to just say done.
People need to be aware that this tool is not a Database Management system.

Suggestions/Capability Requests/Questions that I would like answered
Would like to be able to access predecessor documents that fed into the input for a task assigned to me. Other documents might be nice to. I can understand this access as a security feature, but it seems that at least those predecessor documents should be available to tasks downstream.
Might be more useful for structured analyses that are repetitive in nature, but not good for case-by-case analyses that must be initiated to realize what is required for
A little more user options for uploading documentation would be helpful. Don't limit the output to a single file or file type
Need more evaluation opportunities or test cases.
Compare / contrast for uses within Windchill and/or PARSEC
Would be beneficial if this tool could tie into Windchill / PDM Link somehow to track files and revisions. (maybe it can but it was not used this way on VIPA)

C. Procelerate Responses to Comments and Questions

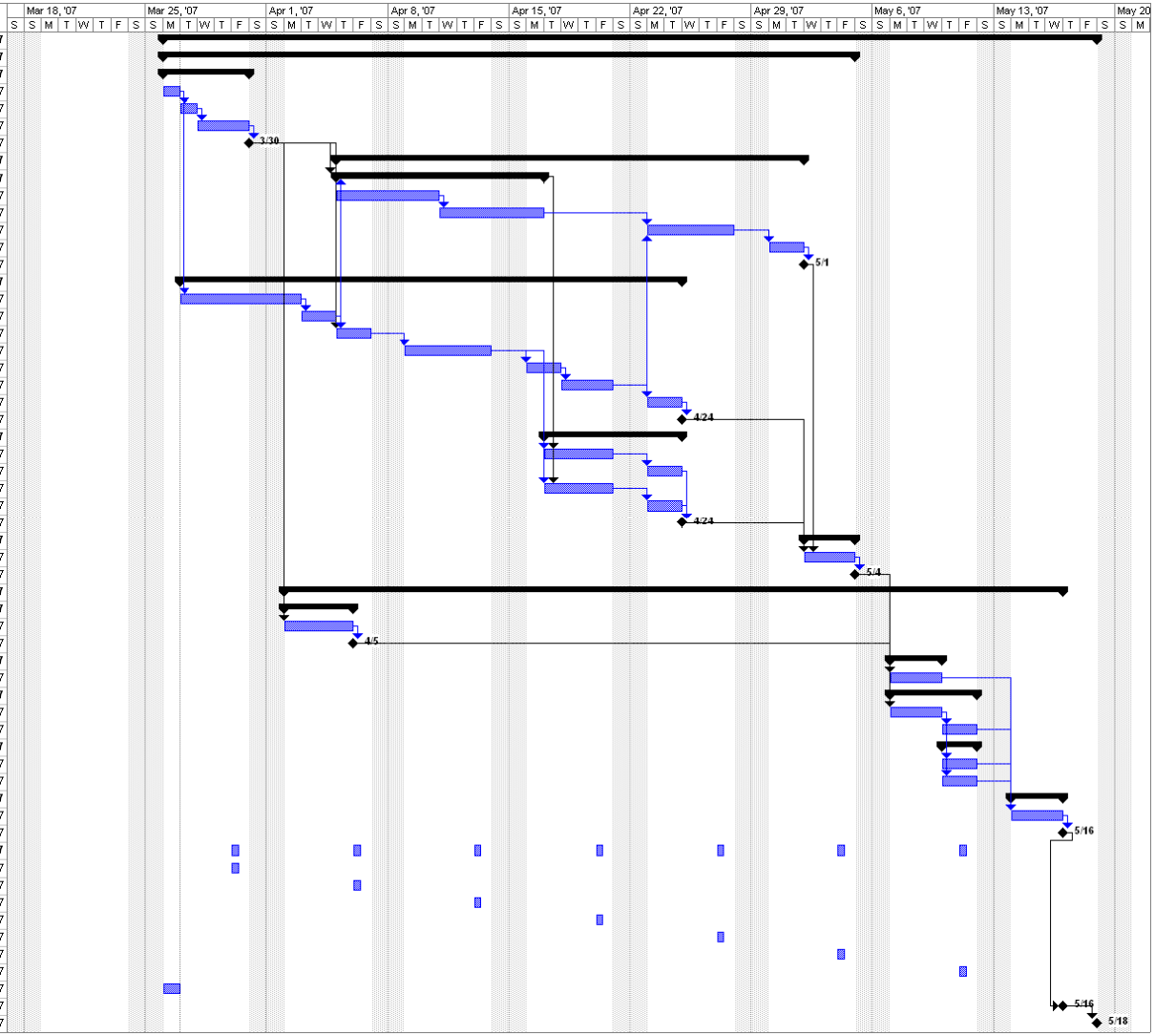
Procelerate welcomes customer feedback and we pride ourselves on quickly responding to suggestions for product improvements. The follow responses correspond to the "Things I didn't like about Vdot" and the "Suggestions/…" comments above.

1. *Comment:* Would really like to see an automated messaging (email) to specific users…
   Response: An instant email feature was incorporated into both the Workbench and VdotWeb within one week of suggestion and is available in UAH's currently installed release.
2. *Comment:* Unless a document (file) was directly tagged as an input to your task…
   Response: Documents may presently be viewed through the workbench interface for all tasks. This feature is being added to VdotWeb as well with the ability set access level privileges.
3. *Comment:* Tasks cannot begin until subsequent [previous?]…
   Response: Tasks can easily be split into multiple tasks which allow some of the activity to begin once the appropriate information is available.
4. *Comment:* Not able to easily add more documentation beyond what was originally requested…
   Response: Using Multi-file types for the data allows attachment of any number of files. Procelerate is also adding the ability to add inputs and outputs to in-work tasks based upon this feedback.

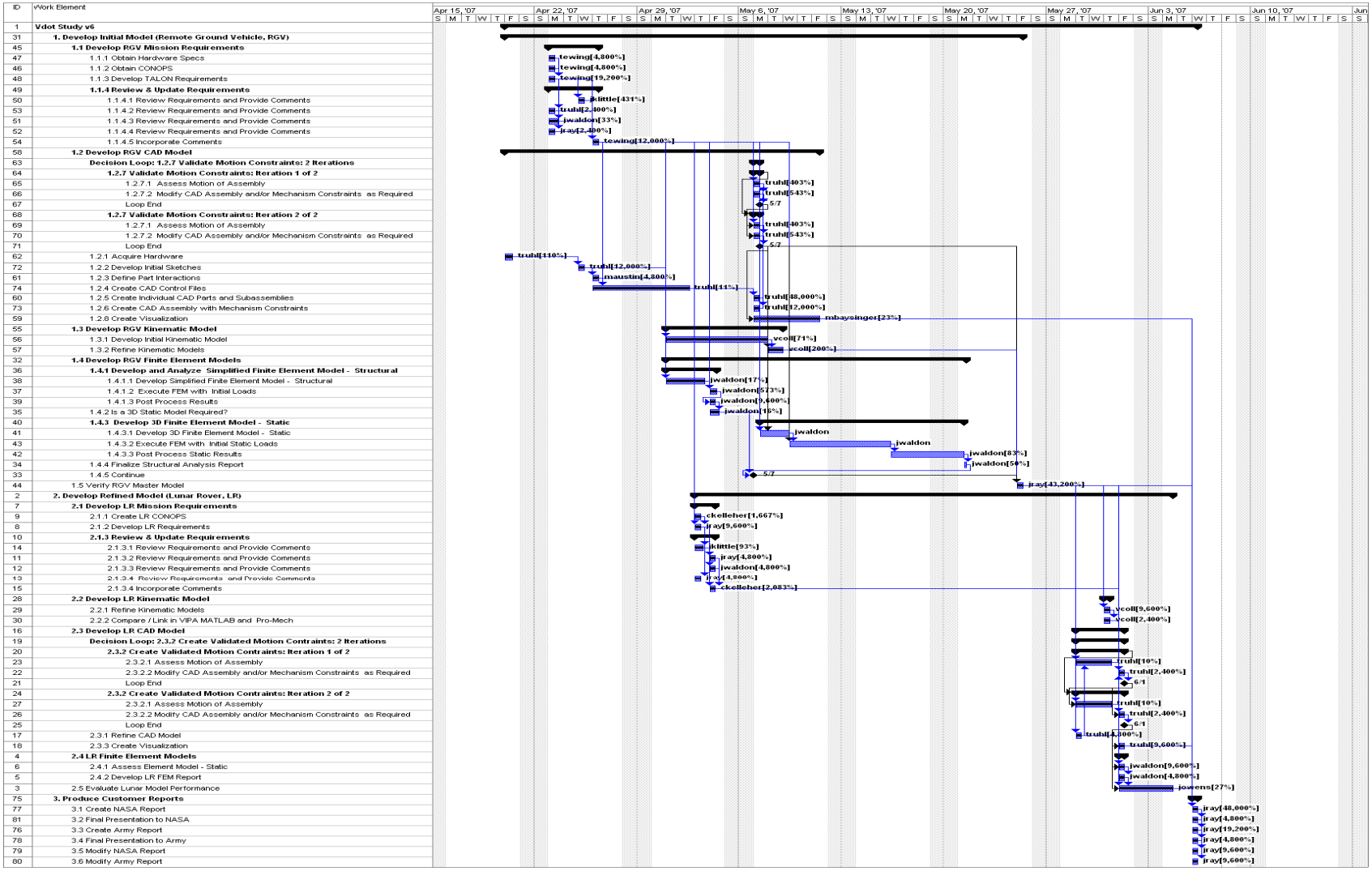
5. *Comment:* Somewhat overloaded with information on first use.
   Response: The ability to hide/unhide columns in dashboards is being added to allow users to customize their individual environment.
6. *Comment:* Very time consuming setup.
   Response: Vdot installation was accomplished in less than one day once the appropriate servers were identified. Network access issues at UAH delayed the ability of remote users to connect. This has been resolved.
7. *Comment:* Web access was not always available…
   Response: See response to Comment 6.
8. *Comment:* Not able to add documentation in format other than that which is requested…
   Response: Using All File Type or Multi-file Type for task inputs and outputs solves this issue; however a specific format may be very important for downstream users.
9. *Comment:* Lose some autonomy and productivity while waiting to be told what is next.
   Response: Proper use of the task list, dashboards and process views ensures that individuals have complete visibility into the state of the entire process. If desired they can delegate tasks to themselves or to others to help move things along more quickly.
10. *Comment:* Still not convinced of its necessity and or utility to manage project.
    Response: We would be happy to discuss this further with the respondent.
11. *Comment:* Hassle with the IT issues.
    Response: See response to Comment 6.
12. *Comment:* Had to attach files for release approval…
    Response: Not required if output is a string type or preset.
13. *Comment:* People need to be aware that this tool is not a Database Management system.
    Response: We would be happy to discuss this further with the respondent.
14. *Comment:* Would like to be able to access predecessor documents that fed into the input for…
    Response: See response to Comment 2.
15. *Comment:* Might be more useful for structured analyses that are repetitive in nature…
    Response: Vdot has been used for all types of processes. We would be happy to discuss this further with the respondent.
16. *Comment:* A little more user options for uploading documentation would be helpful…
    Response: See response to Comment 8.
17. *Comment:* Need more evaluation opportunities or test cases.
    Response: Vdot has been successfully used for many different types of processes. We would be happy to discuss this further with the respondent.
18. *Comment:* Compare/contrast for uses within Windchill and/or PARSEC.
    Response: See Sections 3.1 and 3.4.
19. *Comment:* It would be beneficial if this tool could tie into Windchill / PDM Link…
    Response: Vdot can reference URL locations in Windchill. Also see Section 3.1.

D. Initial Project Schedule (Imported into the Vdot Tool)

ID	Task Name	Duration	Start	Finish
1	**Vdot Study**	**40 days?**	**Mon 3/26/07**	**Fri 5/18/07**
2	**Initial Model Development (Remote Ground Vehicle, RGV)**	**30 days**	**Mon 3/26/07**	**Fri 5/4/07**
3	**RGV Mission Requirements**	**5 days**	**Mon 3/26/07**	**Fri 3/30/07**
4	Obtain Hardware Specs	1 day	Mon 3/26/07	Mon 3/26/07
5	Develop TALON Requirements	1 day	Tue 3/27/07	Tue 3/27/07
6	Requirements Review & Update	3 days	Wed 3/28/07	Fri 3/30/07
7	Requirements Complete	0 days	Fri 3/30/07	Fri 3/30/07
8	**RGV Kinematic Model**	**19 days**	**Thu 4/5/07**	**Tue 5/1/07**
9	**Develop Kinematic Model**	**8 days**	**Thu 4/5/07**	**Mon 4/16/07**
10	MATLAB Version	4 days	Thu 4/5/07	Tue 4/10/07
11	Pro-Mechanica Version	4 days	Wed 4/11/07	Mon 4/16/07
12	Refine Kinematic Models	5 days	Mon 4/23/07	Fri 4/27/07
13	Compare / Link in VIPA MATLAB and Pro-Mech	2 days	Mon 4/30/07	Tue 5/1/07
14	Kinematic Model Complete	0 days	Tue 5/1/07	Tue 5/1/07
15	**RGV CAD Model**	**21 days**	**Tue 3/27/07**	**Tue 4/24/07**
16	Develop Initial Sketches	5 days	Tue 3/27/07	Mon 4/2/07
17	Define Part Interactions	2 days	Tue 4/3/07	Wed 4/4/07
18	Create CAD Control Files	2 days	Thu 4/5/07	Fri 4/6/07
19	Create Individual CAD Parts	5 days	Mon 4/9/07	Fri 4/13/07
20	Create CAD Assembly	2 days	Mon 4/16/07	Tue 4/17/07
21	Create Mechanism Constraints	3 days	Wed 4/18/07	Fri 4/20/07
22	Assess Motion of Assembly	2 days	Mon 4/23/07	Tue 4/24/07
23	CAD Model Complete	0 days	Tue 4/24/07	Tue 4/24/07
24	**RGV Finite Element Models**	**6 days**	**Tue 4/17/07**	**Tue 4/24/07**
25	Develop Finite Element Model - Structural	4 days	Tue 4/17/07	Fri 4/20/07
26	Refine Element Model - Structural	2 days	Mon 4/23/07	Tue 4/24/07
27	Develop Element Model - Dynamic	4 days	Tue 4/17/07	Fri 4/20/07
28	Refine Element Model - Dynamic	2 days	Mon 4/23/07	Tue 4/24/07
29	Element Model Complete	0 days	Tue 4/24/07	Tue 4/24/07
30	**Verify RGV Model**	**3 days**	**Wed 5/2/07**	**Fri 5/4/07**
31	Evaluate Model Performance	3 days	Wed 5/2/07	Fri 5/4/07
32	Verified Master Model (Robotic)	0 days	Fri 5/4/07	Fri 5/4/07
33	**Refined Model Development (Lunar Rover, LR)**	**33 days**	**Mon 4/2/07**	**Wed 5/16/07**
34	**Refine LR Mission Requirements**	**4 days**	**Mon 4/2/07**	**Thu 4/5/07**
35	Develop Lunar Requirements	4 days	Mon 4/2/07	Thu 4/5/07
36	Requirements Complete	0 days	Thu 4/5/07	Thu 4/5/07
37	**LR Kinematic Model**	**3 days**	**Mon 5/7/07**	**Wed 5/9/07**
38	Refine Kinematic Model	3 days	Mon 5/7/07	Wed 5/9/07
39	**LR CAD Model**	**5 days**	**Mon 5/7/07**	**Fri 5/11/07**
40	Refine CAD Model	3 days	Mon 5/7/07	Wed 5/9/07
41	Assess Motion of Assembly	2 days	Thu 5/10/07	Fri 5/11/07
42	**LR Finite Element Models**	**2 days**	**Thu 5/10/07**	**Fri 5/11/07**
43	Assess Element Model - Structural	2 days	Thu 5/10/07	Fri 5/11/07
44	Assess Element Model - Dynamic	2 days	Thu 5/10/07	Fri 5/11/07
45	**Verify Lunar Rover Model**	**3 days**	**Mon 5/14/07**	**Wed 5/16/07**
46	Evaluate Lunar Model Performance	3 days	Mon 5/14/07	Wed 5/16/07
47	Verified Master Model (Lunar)	0 days	Wed 5/16/07	Wed 5/16/07
48	**Update meeting with Don Krupp**	**30.2 days**	**Fri 3/30/07**	**Fri 5/11/07**
49	Update meeting with Don Krupp 1	0.2 days	Fri 3/30/07	Fri 3/30/07
50	Update meeting with Don Krupp 2	0.2 days	Fri 4/6/07	Fri 4/6/07
51	Update meeting with Don Krupp 3	0.2 days	Fri 4/13/07	Fri 4/13/07
52	Update meeting with Don Krupp 4	0.2 days	Fri 4/20/07	Fri 4/20/07
53	Update meeting with Don Krupp 5	0.2 days	Fri 4/27/07	Fri 4/27/07
54	Update meeting with Don Krupp 6	0.2 days	Fri 5/4/07	Fri 5/4/07
55	Update meeting with Don Krupp 7	0.2 days	Fri 5/11/07	Fri 5/11/07
56	Update meeting with Don Krupp	1 day?	Mon 3/26/07	Mon 3/26/07
57	Final Presentation to NASA	0 days	Wed 5/16/07	Wed 5/16/07
58	Final Presentation to Army	0 days	Fri 5/18/07	Fri 5/18/07



E. Final Project Schedule (Exported from Vdot Tool)



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