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Modeling Constellation Virtual Missions Using the *Vdot*™ Process Management Tool

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ABSTRACT

The authors have identified a software tool suite that will support NASA's Virtual Mission (VM) effort. This is accomplished by transforming a spreadsheet database of mission events, task inputs and outputs, timelines, and organizations into process visualization tools and a Vdot process management model that includes embedded analysis software as well as requirements and information related to data manipulation and transfer. This paper describes the progress to date, and the application of the Virtual Mission to not only Constellation but to other architectures, and the pertinence to other aerospace applications. Vdot's intuitive visual interface brings VMs to life by turning static, paper-based processes into active, electronic processes that can be deployed, executed, managed, verified, and continuously improved. A VM can be executed using a computer-based, human-in-the-loop, real-time format, under the direction and control of the NASA VM Manager. Engineers in the various disciplines will not have to be Vdot-proficient but rather can fill out on-line, Excel-type databases with the mission information discussed above. The author's tool suite converts this database into several process visualization tools for review and into Microsoft Project, which can be imported directly into Vdot. Many tools can be embedded directly into Vdot, and when the necessary data/information is received from a preceding task, the analysis can be initiated automatically. Other NASA analysis tools are too complex for this process but Vdot automatically notifies the tool user that the data has been received and analysis can begin. The VM can be simulated from end-to-end using the author's tool suite. The planned approach for the Vdot-based process simulation is to generate the process model from a database; other advantages of this semi-automated approach are the participants can be geographically remote and after refining the process models via the human-in-the-loop simulation, the system can evolve into a process management server for the actual process.

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I. Introduction

NASA Virtual Missions (VMs) are tabletop, paper-based simulations of the processes and resource flows during a mission. They are used to uncover gaps and timing issues in the execution of tasks by different organizations that support a mission and to validate new procedures and mission support software. Representatives from each operations center (JSC, MSFC, and KSC) contributed a list of the set of processes and products their organizations were responsible for to a central database which were then retrieved during the course of the VM and "executed" in bi-weekly meetings. This paper discusses the utilization of this information to further the VM discovery process by creating visualizations of the VM data and proposing the use of software tools in carrying out the automation of the mission operation processes.

II. Background

Historically, VMs were conducted in a paper-based environment. Representatives from each organization involved in conducting tasks during a mission contributed a list of defined tasks to the VMTS database. One of the tasks is shown in **Fig. 1**. Information in the form included the number of days prior to launch the task was to begin and end (L-day), a description of the task, the resources produced by the task, and the dependencies of the task on other organizations' tasks. A launch day was then selected and the mission began 8 months prior to the launch day. Bi-weekly meetings were then held during which each set of tasks corresponding to the appropriate L-day were reviewed by the team. Any mismatches in resource flow or timing sequences were discussed and actions were taken to address the situation. Advantages of a paper-based simulation or role-playing game include flexibility, free-flowing ideas, and low cost. If the participants capture the ideas, the exercise can result in appropriate requirements and refined procedures. Limitations of this type of simulation are the time involved, level of detail in the scenarios, and knowledge of the particular participants. An effort began in early 2010 to automate and create a server based VM simulation.

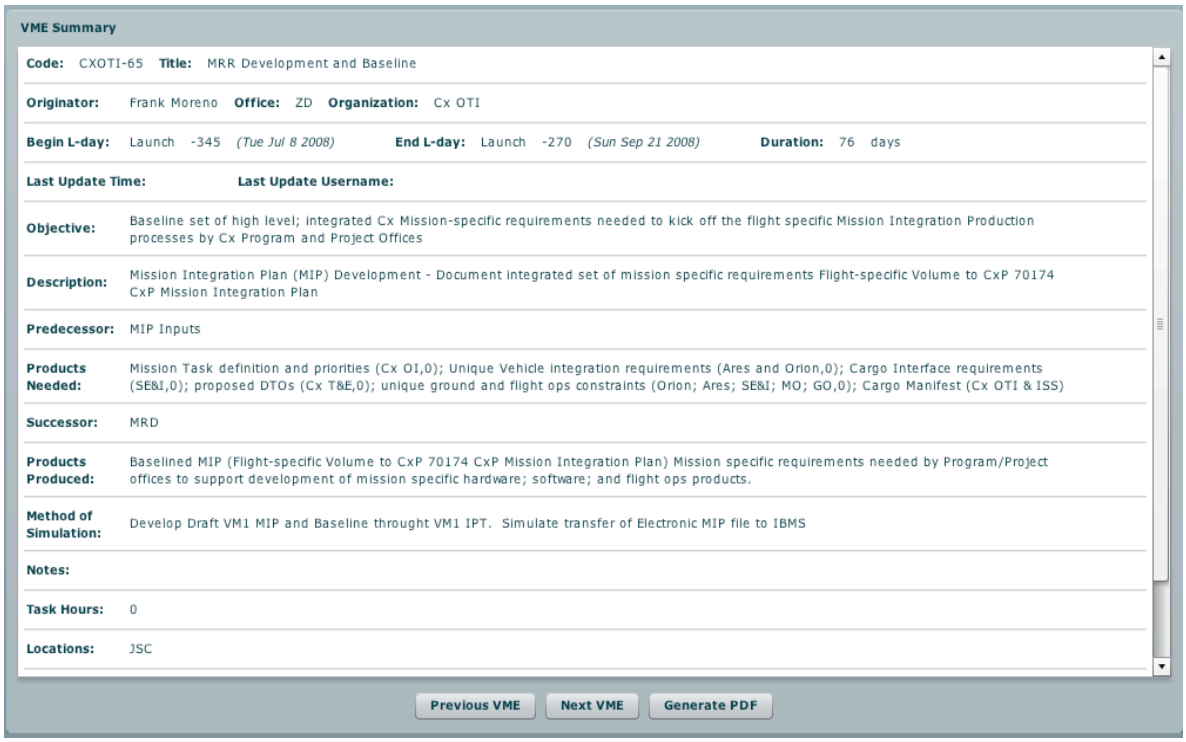

Figure 1. Virtual Mission Task Description

The planned approach for the Vdot-based process simulation was to generate the process model from a database to which subject matter experts (SMEs) contributed information about products, processes, procedures, timelines, and interrelationships. Other advantages of this semi-automated approach are the participants can be geographically dispersed and, after refining the process models via the human-in-the-loop simulation, the system can evolve into a process management server for the actual process execution. Vdot also allows the Mission Manager to monitor the progress of each task in the mission and reallocate resources as needed to maintain schedule or modify it as necessary.

Both the paper-based and process server-based simulation methods are beneficial. Early in a program, the paper-based simulation serves as an excellent brainstorming exercise that leads to greater appreciation of all the process disciplines and it can generate requirements for the computer-based human-in-the-loop and fully automated process simulations. The intent of the virtual missions was to engage personnel from across the agency to rehearse future missions, identify problem areas, and optimize processes.

III. Approach

The authors' work to develop an experimental process engineering tool suite to enable the VM was developed by considering a mix of COTS products and customized coding. Process integration efforts sponsored by the Constellation Program included activities to transform a data set that described a virtual mission into a collection of diagrams, a computer simulation, and a human-in-the-loop managed process simulation. **Fig. 2** depicts the process engineering tool suite. A web-accessible database in the upper left corner of the diagram provides a means of crowd-sourcing process data collection. Process participants fill out a web-form to explain their data needs, describe their tasks, define their products, and identify their stakeholders. An Excel workbook contains data exported from the database. Macros translated the data into a variety of file formats including Dot, Microsoft Project, eXtended Markup Language (XML) Process Definition Language (XPDL), and XML Metadata Interchange (XMI).

Applications imported these files to generate diagrams, simulations, and managed work-flows. Graphviz, a free network visualization program developed by AT&T, transformed the Dot file into a Data Flow Diagram (DFD), which enabled the process integration team to quickly identify orphans, redundancies, and incorrect data flows. Business Process Modeling Notation (BPMN) tools in Fig. 2 include Savvion, BizAGI, and TIBCO Business Studio. Advantages of BPMN diagrams include interactions among processes that cross organizational boundaries, a capability to drill down to lower levels of detail, and capabilities to indicate iterative tasks and methods of data transfer. Additionally, the TIBCO Business Studio provides a capability to produce a simulation by assigning resources to BPMN diagrammed activities. Bar and Pie charts generated from the simulation provide information about process throughputs and bottlenecks.

This same approach of capturing data via a database or spreadsheet and translating the data into a text file for import by a diagramming tool also works for system interfaces as well as business processes. Another file-type identified in Fig. 2 is the Cradle export file format. A parallel activity produced a data set that described launch vehicle system interfaces. The interfaces were described in an Excel workbook and macros generated the Cradle file. Several extended Functional Flow Block Diagrams (eFFBD) were generated from the imported Cradle file.

A Microsoft Project file generated from the data-set enables the generation of activity network diagrams similar to the Process Evaluation Review Technique (PERT) and Gantt charts; these diagrams facilitate conversations about resources and schedule. Simulating a business process requires resource and schedule data.

Two process management systems appear at the front of the applications column in Fig. 2: Vdot and Bonita Open Solution. Both of these server-based systems manage workflows depicted in a process diagram. Bonita Open Solution presents BPMN diagrams and imports XMI files. Vdot presents processes in a graphic notation derived from the Interface Definition (IDEF) standard and it imports Microsoft Project files

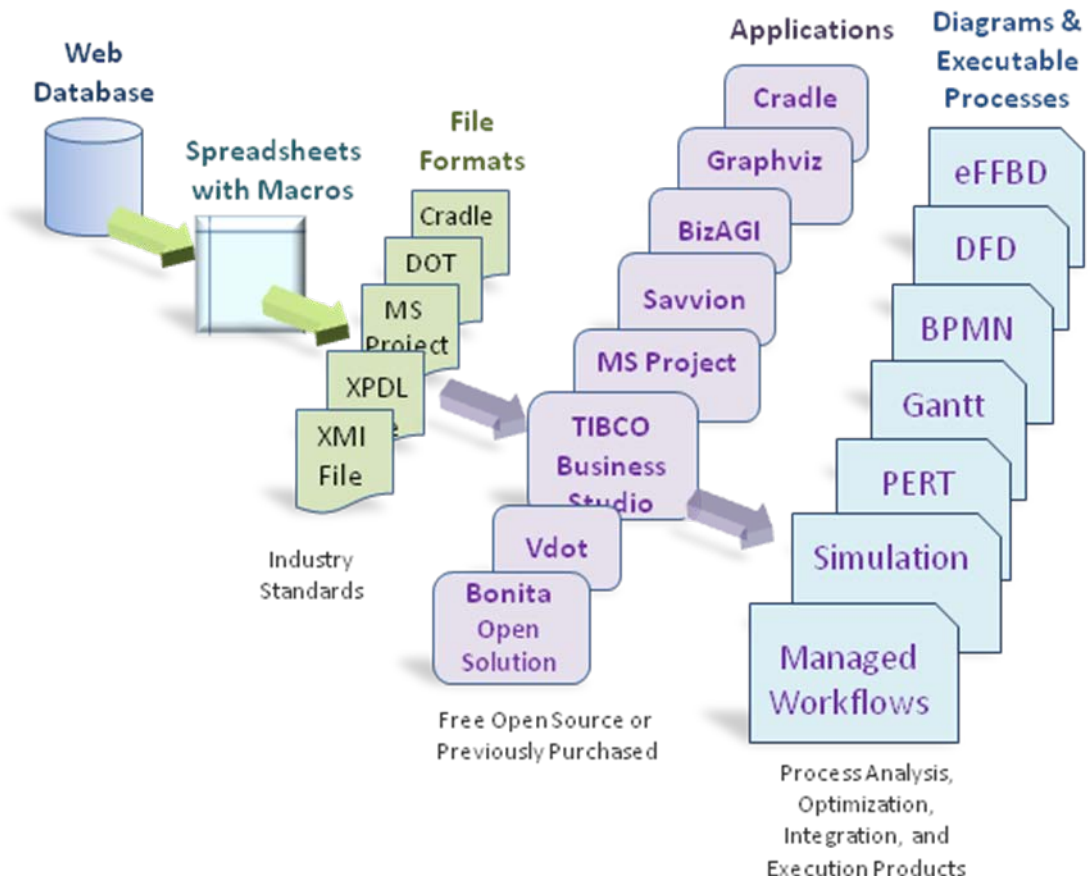

Figure 2. Process Engineering Tool Suite

With a tool suite that enables crowd-sourcing process data collection, visualizing process networks, simulating processes, and deploying managed workflows, an organization can establish round-trip process engineering. **Fig. 3** depicts this concept of round-trip process engineering. Through databases and spreadsheets, a process integration team captures data-sets of needs, activities, products, and stakeholders. Generated diagrams, including DFD, PERT, Gantt, and BPMN, facilitate conversations about data flows, skills, products, and times. Process models generated from the data enable the development of simulations and deployment of executable work-flows. Colors in Fig. 3 indicate four categories of activities: capturing and refining process data, diagramming or improving process models, generating process models or generating process metrics, and simulating or deploying executable process models. Multiple iterations of this engineering process enable organizations to continuously improve their businesses and produce reusable process models for developing new business processes.

The first step in the server-based VM simulation is the creation of a Virtual Mission Task Sheet database. Requirements are entered in an MS Excel spreadsheet specially formatted with fields that can be identified and parsed by subsequent macro executions; these Excel macros generate a variety of process description files from the virtual mission data set, which then pass the data to a MS Project file and then into Vdot. This quickly captures an organizational process from a large number of subject matter experts. Diagrams generated by the imported files enabled a variety of analyses and process simulation, and files were imported into data visualization, simulation, and management tools. **Fig. 4** shows a case study example for the computer-generated diagrams of a Virtual Mission. Of utmost importance in this process is "spreadsheet discipline." The SMEs who initially enter the data must do so in strict conformance with the formats identified in the various entry cells. Otherwise, much time can be lost having to revise information to suit the parsing algorithms of the macros that transform the data into the process visualizations, or worse, the information will not be accurately transferred to the other tools.

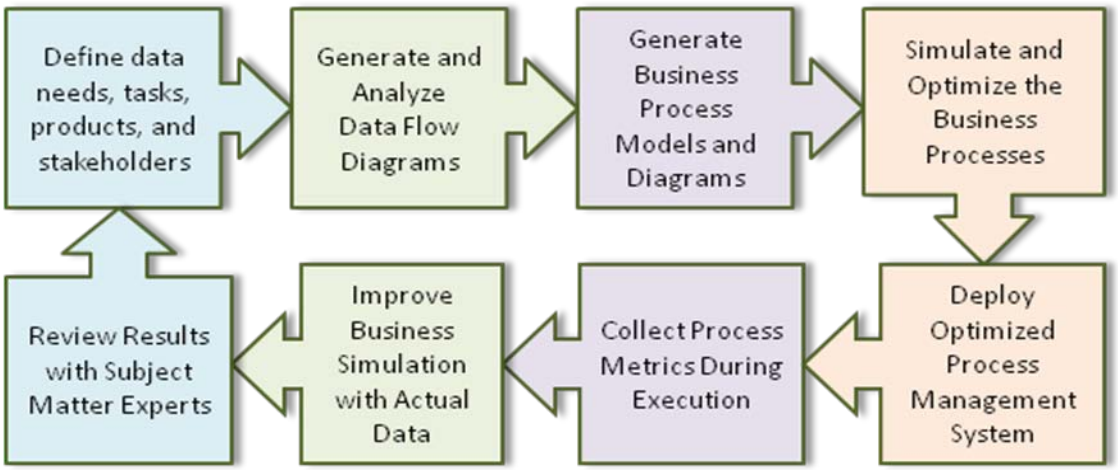

Figure 3. Round Trip Process Engineering

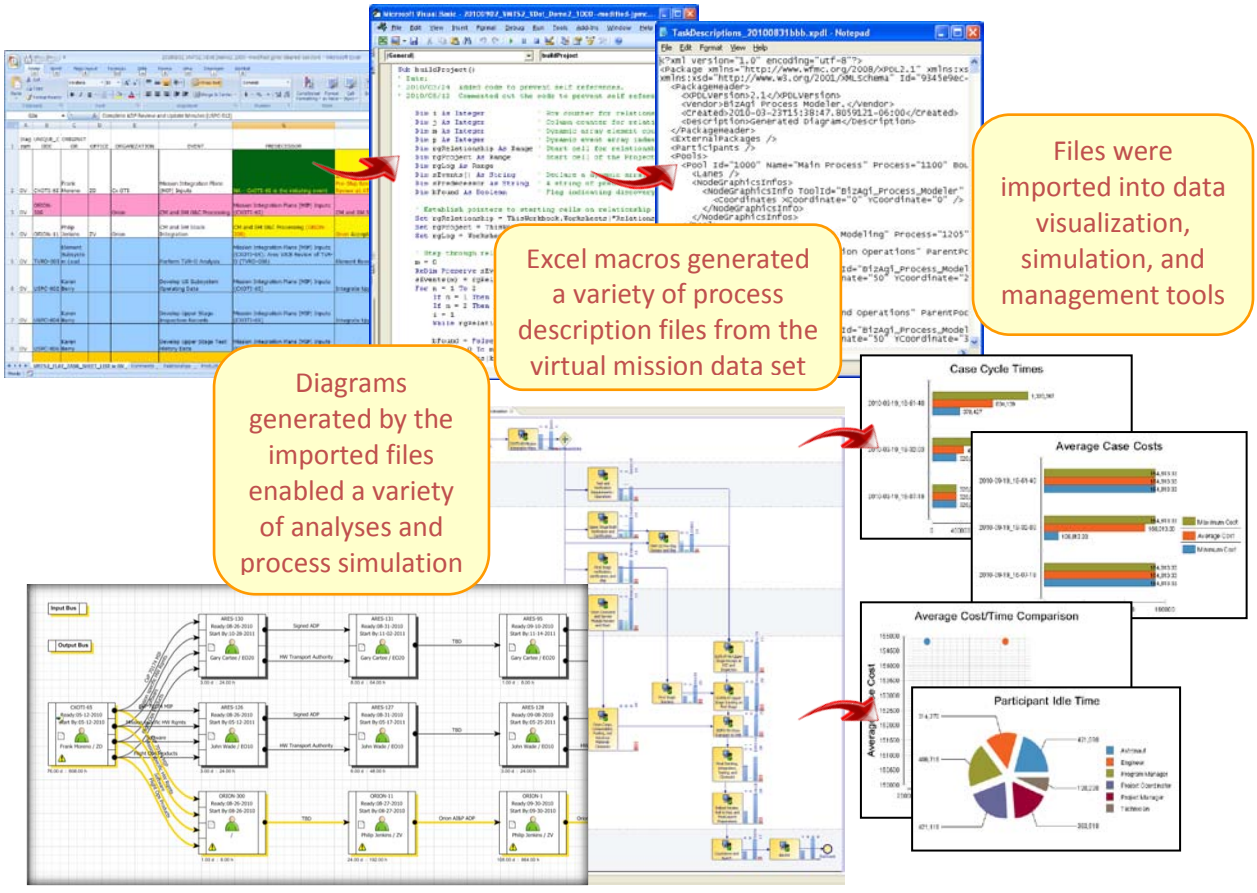

Figure 4. Case Study Example, Computer Generated Diagrams for Virtual Missions

IV. Vdot Primer

At this point of the paper, it is prudent to introduce the working details of the Vdot process management tool, or platform. To succeed in improving the efficiency of any team, you must first capture the processes employed to a sufficient level of detail to understand the flow of information or deliverables required to produce your end product/s. To do this, most facilitators gather a group of SMEs together to create a process diagram or value stream map. Typically, the team uses poster or butcher paper and sticky notes to capture the information, and then manually transfers that data to a picture in PDF format, MS 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 of the key parties to physically be together in a room to collaborate on the process definition. In addition, the diagrams are static, and there is no way to easily deploy them to your teams. Testing of the processes is essentially an academic exercise, and the documentation may quickly become outdated and unused. To address these concerns, a group of engineers from The Boeing Company developed a software platform called Vdot. The name is derived from the mathematical symbol for the derivative of velocity which is acceleration. Vdot is now a commercial-off-the-shelf (COTS) 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 it provides automatic real-time project status which increases an organization's efficiency and productivity. Vdot's capabilities have been used on a wide variety of engineering and business processes.

Vdot's point and click graphical interface (**Fig. 5**) allows you to quickly and easily define 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. This includes parts, fasteners, tools, work instructions, and timing information to ensure the task is completed efficiently. 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 (**Fig. 6**). Vdot then makes it easy to define the flow of information between process participants so you have a true awareness of "who needs what from whom". This visual map helps identify undocumented steps in your processes that may be significantly impacting throughput. It also highlights areas where tasks are being worked sequentially that could actually be worked in parallel. The visual representation provides a convenient way to inspect the overall process for the desired Critical to Quality (CTQ) attributes that are important to the success of your efforts. Vdot enables you to define the key measurable characteristics of both the product and the process in order to later quantify the CTQs. Vdot also serves to harvest Earned Value Management (EVM) data (e.g., estimated duration, actual duration, estimated work, actual work, etc.) and automatically stores it in the underlying database with the incorporated Vdot engine. With Vdot, there is no need to have the entire process documented to start using it – processes can be defined at a high level as a starting point and continuously refined along the way using nested processes. By double-clicking on a nested Smart Task (shown as a double stack of "books" in the Smart Tasks of Fig. 5), you are able to instantly navigate into the sub-process and add the detailed steps necessary to define that level of the process. Processes can be nested to any level of detail you desire. This makes understanding and communicating your processes much simpler and also aids in compartmentalizing the process definition. Process definition may be performed either in a group setting or you can divide up the work and collaboratively diagram and document your processes from distributed locations. A trial VM is depicted in Vdot in **Fig. 7**. This was created by the custom macros for MS Project generation, XML Process Definition Language (XPDL) file generation, XML Metadata Interchange (XMI) file generation, Dot notation generation and the tools that use those files.

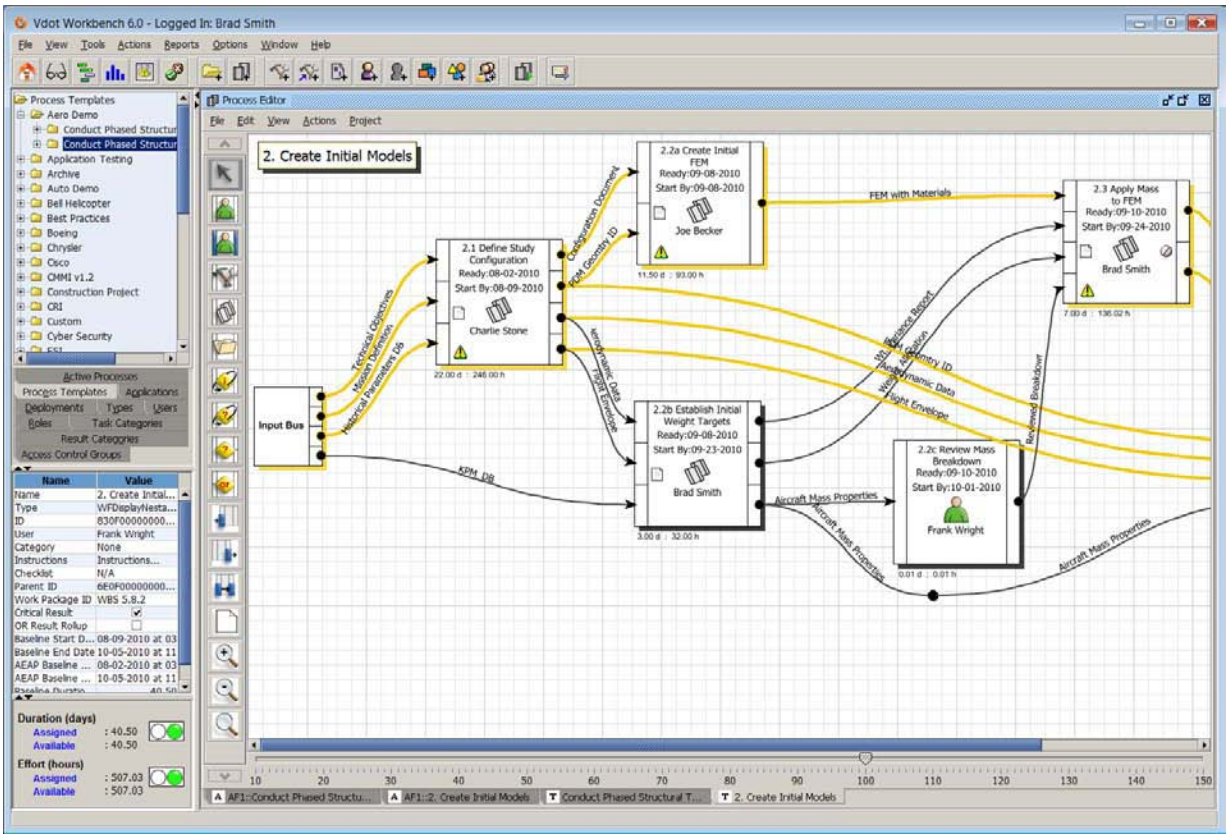

Figure 5. Defining Value Streams using Vdot's Process Editor

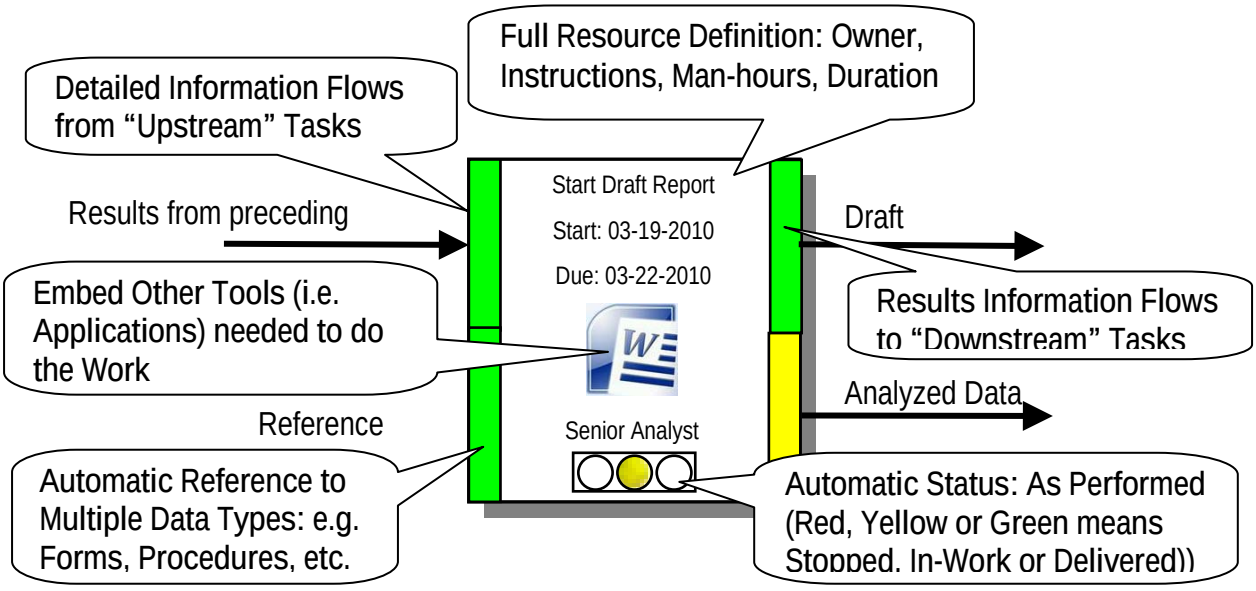

Figure 6. Vdot Smart Task

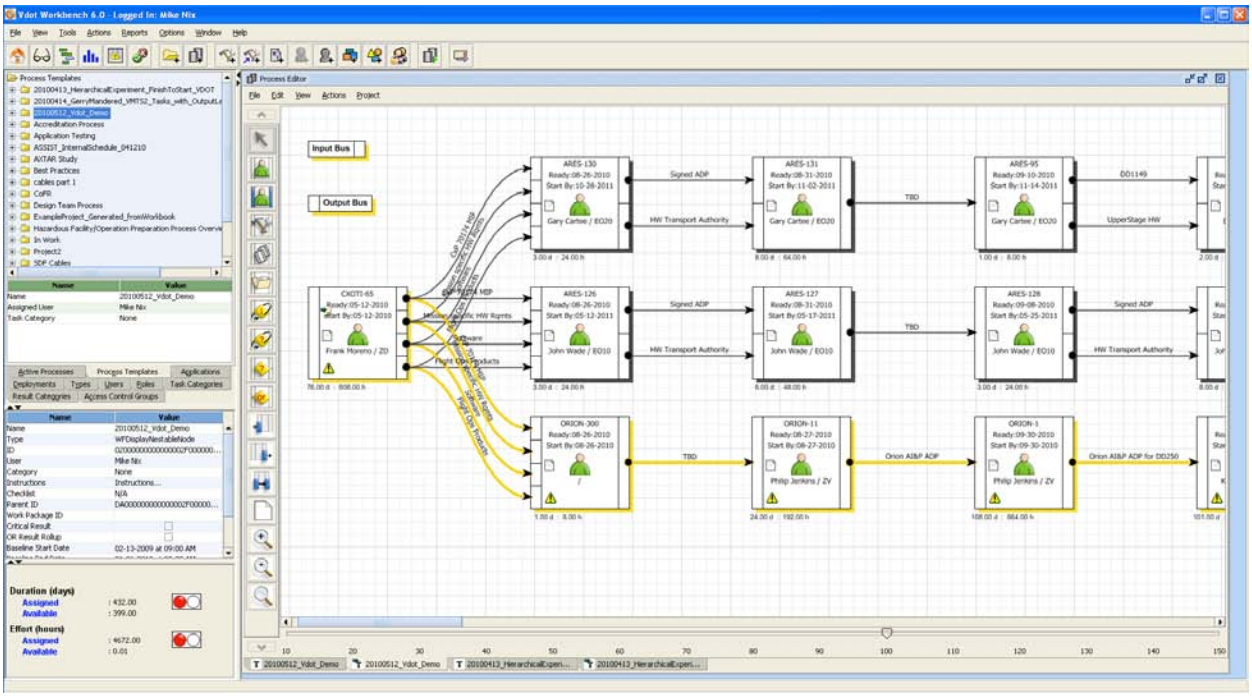

Figure 7. NASA VM example depicted in Vdot

The VM tool suite includes Vdot, MS Project, Graphviz, Bonita Open Studio, and TIBCO Business Studio. Both Vdot and Bonita Open Studio are process management systems. While Vdot is a commercial product with an emphasis of integrating desktop applications into a process, Bonita Open Studio is an open source product with an emphasis of integrating server-based collaborative software. The Bonita Open Studio can read an XMI file and Vdot can read an MS Project file. A graphic notation derived from the Interface Definition (IDEF) is used by Vdot and the Business Process Modeling Notation (BPMN) is used by Bonita Open Studio.

Graphviz, a free tool developed by AT&T, provides a powerful network and data-flow diagramming capability, which was used extensively to identify process orphans, redundant activities, missing activities, and wrongly wired data-flows. A notation, named Dot, enables a text file to describe a complex network to be rendered by Graphviz. The TIBCO Business Studio is a free process modeling tool built upon the Eclipse integrated development environment; it imports XPDL files and depicts processes in BPMN. A powerful function of the TIBCO Business Studio is stochastic process simulation. Using TIBCO Business Studio, a team simulates a process and optimizes it before automating it with a process management system.

V. Virtual Mission Process Modeling

In the past, process modeling experts conducted a series of interviews with SMEs or workshops, where the VM is discussed and the experts interpreted interviews and collected documentation examples. These experts then developed diagrams of data flows or process models, and presented the diagrams to the SMEs to confirm the accuracy of the depictions. The final product usually required a number of iterations of this process as the modeling experts and process owners converged on a common understanding and agreement on the models. A new approach engineered by the authors is to conduct a crowd-source process data collection with database or collaboration tools. Crowd sourcing is a concept of capturing data from a wide variety of people to solve a problem. A database or collaborative discussion tool can quickly collect people, process, and product information for automated diagram generation tools, where the computer generates the diagrams and publishes them for the community to review. The virtual mission task sheet database served as a crowd-sourcing tool to collect activity and product descriptions that would flow through the organizations during a mission.

This focuses discussions on orphans, redundancies, and mismatched input/output, and helps develop process simulations to identify bottlenecks or places where the process could be refined. The computer is then used to generate an execution management model of the optimized process, and create human-in-the-loop simulation to experience workloads and info links. A process management engine has significant advantages over more conventional approaches. For example, some people work several projects; automated e-mail notifies them when it is time to support a particular task. These tasks are a managed process which includes links to files and/or tools needed to perform the work. The Vdot process management engine captures actual process steps that support future planning. Processes can be developed in an iterative fashion; human in the loop-simulation allows the process development team to rehearse tasks. A single authoritative data source with file export utilities and process modeling tools can generate a variety of diagrams for different types of analysis.

VI. Conclusions

Several in-house trials have been performed to date using data from the initial two VM experiments, which were performed as paper-based simulations to test the process. The new approach utilized computer-generated data flow diagrams, which enabled the team to visually inspect the virtual mission data flow and identify orphans, redundancies, and mismatched inputs and outputs. The computer-generated VM was successful from the standpoint that it allowed a small team, using process data generated from earlier experiments, to develop a human-in-the-loop simulation of a mission planning event. In-house trials proved that the human-in-the-loop simulation was much more powerful and efficient with the automated computer generated process. A clear direction has been established for future evolution into a fully implemented mission process management server.

A multi-center, geographically-distributed VM demonstration is planned. A recommended approach for future projects could start with a paper-based simulation to identify process and data requirements; next, build a web-database to capture participant, process, and product descriptions, and then apply this assembled tool suite to visualize, optimize, integrate, and automate the process.

VII. Acknowledgements

The authors would like to acknowledge Mr. Donald Monell, Manager of the Constellation Information Systems Office, and Dr. Alonso Vera, Manager of the Application and Process Integration Office, Constellation Information Systems Office, for their leadership and foresight in this endeavor.