

The Semantic Web and Space Operations

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ABSTRACT

In this paper, we introduce the use of ontologies to implement the information developed and organized by resource planning tools into standard project management documents covering integrated cost, resource modeling and analysis, and visualization. The basic upper ontology used for NASA Space Operations is explained and the results obtained are discussed. This ontology-centered approach is looking for tighter connections between software, hardware, and systems engineering.

INTRODUCTION

Space Operations and their “space launch” products have evolved from a small group of people launching rockets from a large empty field to launches involving a large number of resources from mega launch complexes (Cates et al., 2002; Rabelo et al., 2004; Rabelo et al., 2006a; Rabelo et al., 2006b; Rajkumar and Bardina, 2004). As a space center's launch complexity is increased, new tools need to be developed for effectively organizing operations data and processes. For example, NASA KSC has developed a tool using a Microsoft Excel environment that is automated through the use of 1) Microsoft Visual Basic for applications in determining workforce requirements and 2) artificial intelligence methodologies for case-based reasoning for the purpose of integrating the planning and design of a space launch project with the particular project management schedules and sequence of operations.

When executing the current software environment (Ellis, 2005) for individual launches, a standard Work Break-down

Structure (WBS) is often used. Requirements from the WBS for each launch are assigned to begin a month prior to launch. The WBS specifies the resources to be used (e.g., human and hardware), the sequence of activities and the required resources, the products to be delivered, and the deadlines. The problem with the current approach is that several relationships are excluded. For instance, the emphasis has been on depicting, in a static form, the information (e.g., Microsoft Excel Spreadsheets) and not the visualization and/or simulation of the activities. In addition, the current software environment does not utilize the standard tools for project planning such as Microsoft Project. Microsoft Project allows the user to plan a project utilizing simple Gantt charts with the ability to assign resources to each task and identify task precedents.

The following sections address the possibility of transferring the information developed and organized by the resource planning tools into standard project management products that utilize an ontology centered-approach in order to incorporate integrated cost, re-source modeling and analysis, and visualization. Two case studies are introduced. The first case study is the schedule and resource requirement to perform the mating of the different components of the NASA Space Shuttle stack. The second case study demonstrates the potential to generate the work-breakdown structure (WBS) and its depiction using Microsoft Project. Finally, conclusions and future work are presented.

ONTOLOGIES

Gruber (1993) defines ontology as a formalization of a conceptualization. A more precise and applicable description with respect to this work is a hierarchy of subsuming

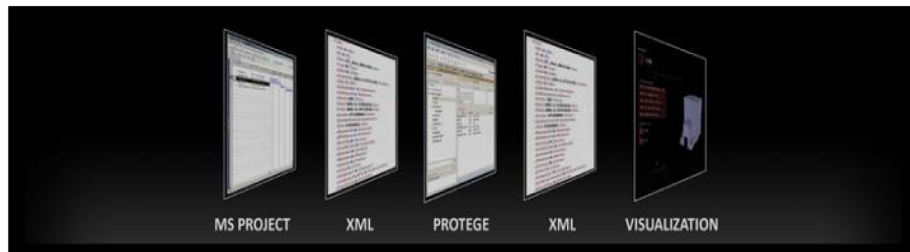


Figure 1. Approach utilized from MS Project to XML-Protégé-XML into Visualization Engine

concepts supplemented with semantic relations that further define how concepts are interrelated (Tolk and Turnista, 2007). Within the past decade, ontologies have been adopted across a variety of domains. For example, the Gene Ontology was created to standardize gene representation across species (The Gene Ontology Consortium, 2010). Another example is the semantically-rich Foundational Model of Human Anatomy Ontology (Rosse and Mejino, 2007) which contains over 75,000 anatomical and physiological concepts.

Some researchers have applied ontologies to aid in the construction of frameworks for simulation applications. A prime example of this is the Ontology-Driven Simulation (ODS) framework created by Silver et al. (2007). The ODS framework consists of a mapping phase where users map concepts in their domain of interests (e.g., healthcare, military) to simulation concepts in DeMO. After the domain concepts are aligned with simulation concepts, a markup file can be generated that can run in the Java-based simulation environment JSIM (Miller et al., 1999) or the commercial simulation package ARENA. Another ontology-centric approach is the Framework for Adaptive Modeling and Ontology-driven Simulation (FAMOS) (Benjamin et al., 2006). Modeling in FAMOS entails selecting and editing templates and composing models together from library components including ontologies for different domains and process models. Simulation and domain ontologies can be utilized in FAMOS and it provides a model composition tool with a “visual programming” interface in support of the composition of distributed, federated simulations systems.

We are leveraging ontologies to achieve our goal of synthesizing NASA's disparate engineering and organizational data. An ontological approach can be employed to map vehicle architectures/space launches and mission requirements to project management and from project management to resources, constraints, costs, visualizations, and simulation models through analysis of the semantic relationships between ontology members (see Figure 1).

NASA PROGRAMS, PROJECTS, MISSION, AND SYSTEM CONCEPTS

Within NASA, some major concepts are the ones referred to as programs, projects, and missions. There are four main types of programs:

Single-Project Programs: These programs have long development and/or operational lifetimes, and represent a large investment of NASA resources in one program/project. Multiple organizations are stake-holders of this type of program.

Uncoupled Programs: These programs are implemented under a broad scientific theme such as “providing frequent flight opportunities for cost-capped projects. Each project is independent of the other projects within the program.

Loosely Coupled Programs: These programs address specific scientific or exploration objectives through multiple space flight projects (i.e., missions) of varied scope. While each individual project has an assigned set of mission objectives, architectural and technological synergies and strategies that benefit the project as a whole, there are also certain commonalities being exploited. posed of numerous space flight projects (missions) involving different centers and even international partners. The same space flight hardware is assigned and the architecture and technological elements are common during the missions (Figure 2).

Missions are space flight projects. All space missions consist of physical and functional elements (Figure 3).

It is important to clarify that missions include these basic elements to some degree. As stated by Larson and Pranke (2002), “System requirements flow from the space- and ground-based operators, end users, developers, and sponsors to the various mission elements.” The design of a mission is a creative process where we have to develop several alternative mission concepts (i.e., broad statement of how the mission will work in practice), and the supporting infrastructures necessary to meet particular objectives. “Our goal is to select the best overall way to conduct a space mission and to provide a traceable rationale that decision makers can understand.”

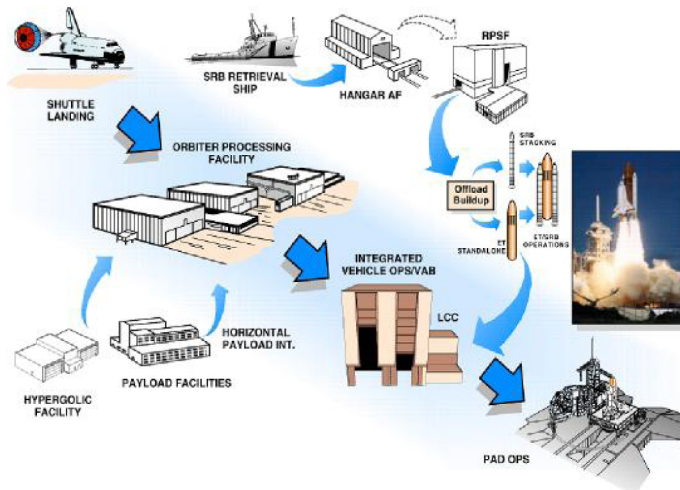


Figure 2. Process flow for a Shuttle Mission (Source: NASA)

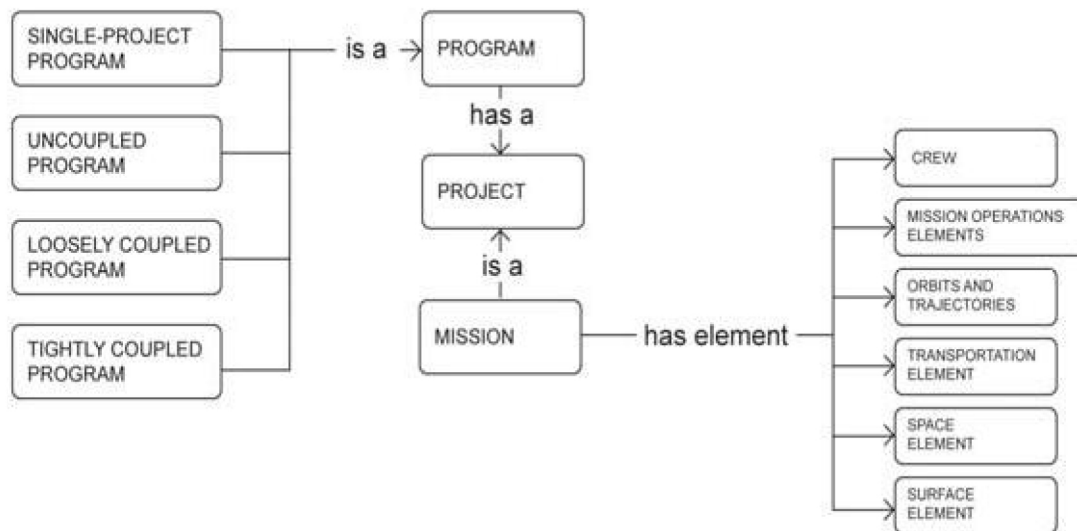


Figure 3. Ontology derived from high level NASA concepts pertaining to "Programs."

VISUALIZATION AND A HYPERLINK ONTOLOGY ENVIRONMENT

The case study presented in this section centers around the task of mating the Orbiter to the ET and SRB stack. A high-level illustration of the software that was created for this case study is shown in Figure 4.

The Shuttle mating process is defined organizationally through a Gantt chart, with task dependencies and resource allocations via MS Project. This sub-task is explained as follows:

External Tank (ET) Transfer to VAB: Moving the External Tank to the VAB. The ET arrives at KSC on a barge which is

docked in the turn basin near the press site. The ET is inspected, then off-loaded from the barge utilizing a special trailer and towed to the VAB transfer isle where it is stored until it is integrated with the SRB stack [<http://science.ksc.nasa.gov/facilities/vab.html>, accessed March 1, 2011].

SRB Stacking in the VAB High Bay: The Solid Rocket Motor (SRB) stacking consists of placing an SRB's aft skirt onto hold-down posts on the Mobile Launch Platform (MLP) in one of the VAB High Bays (HB). The SRBs are then stacked one segment at a time until all four segments are stacked. At this time the forward extension is added that houses the avionics and parachutes and SRB stacking is complete (The MLP sits on six pedestals. When it is ready to go to the pad, a crawler pulls underneath, raises the MLP