Reengineering the Mission Operations Directorate Flight Production Process

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The Mission Operations Directorate (MOD) at NASA Johnson Space Center (JSC) is responsible for operating the NASA human flight programs. The MOD Mission Operations System (MOS) includes the infrastructure, people, and processes that are used to "plan, train, and fly" the corresponding space missions. The MOS has been refined over time, and the underlying know-how that allows the system to run smoothly is inherent in each of the system elements. Reengineering the MOS to meet the MOD goal to reduce sustaining costs by 50% as compared to space shuttle missions entails fully characterizing the MOS, understanding its strengths and limitations, identifying the gaps between its current capabilities and those required for meeting future program needs, and designing a feasible transition plan for reaching the desired end state.

The MOD Space Shuttle Program and International Space Station Program flight production processes (FPP) were not built as an integrated system. The separate and distinct production processes used for these two programs were instead built one piece at a time by each of the large functional areas within MOD. These processes have been streamlined and refined over time, but never engineered to maximize efficiencies. Today, MOD produces more than 600 products for each shuttle mission to the International Space Station. These products are manually integrated at a high level called the management level. While this high-level integration process allows MOD to meet its top-level product delivery requirements, it does not provide sufficient insight into the processes necessary to understand, integrate, or reengineer the detailed processes.

The FPP Reengineering Project has established a model-based systems engineering methodology and the technological infrastructure to design and develop a reference, product-line architecture as well as an integrated workflow model for the MOS for human space exploration missions. The design and architectural artifacts have been developed based on the expertise and knowledge of numerous subject matter experts. The technological infrastructure developed by the FPP Reengineering Project has enabled structured collection and integration of this knowledge and further provides simulation and analysis capabilities for optimization purposes. A key strength of this strategy has been the judicious combination of commercial off-the-shelf products with custom coding. This foundation is now being extended to include the breadth of the processes involved in the operation of human and robotics missions, and is being used to guide the redesign of the Mission Control Center.

Goals of the FPP Reengineering Project are achieved by using cutting-edge systems engineering techniques to model the processes involved in the development of flight products and finding an optimal strategy for allocating resources to each of these processes. Figure 1 shows a high-level architecture for the model that is being built. This architecture includes multiple layers. At the lowest level is the layer that includes the views generated based on the Department of Defense architecture framework. This layer is used to define and analyze the relationships between the key attributes of the system and their interfaces. On the right side is a database that includes the underlying data for the system; these underlying data in turn feed all of the layers. This database is updated as the system is designed, and will continue to be updated even after it operates and more data become available. The next layer includes executable models such as the discrete event simulations and risk models that are used to validate the end-to-end architecture of the system. The actual MOS depicted in this layer uses the data available in the database to run simulations and demonstrate system performance metrics such as the minimal cut-sets of the system, critical paths, and probability distribution function of the time to complete a full run. The MOS depicted is the actual system that is being designed during the design phase and will be used to perform operations. During the operations phase, the actual measures of system performance are produced by this layer and fed back into the database, as are other layers of the model as necessary for continuous improvement.

The topmost layer is the manage and control layer, which serves the function of orchestration and uncertainty management. The orchestrator is called the management-level network executive and uncertainty management is conducted by a replanning tool. The management-level network executive has a direct interface with components of the MOS and sends commands to them to automatically

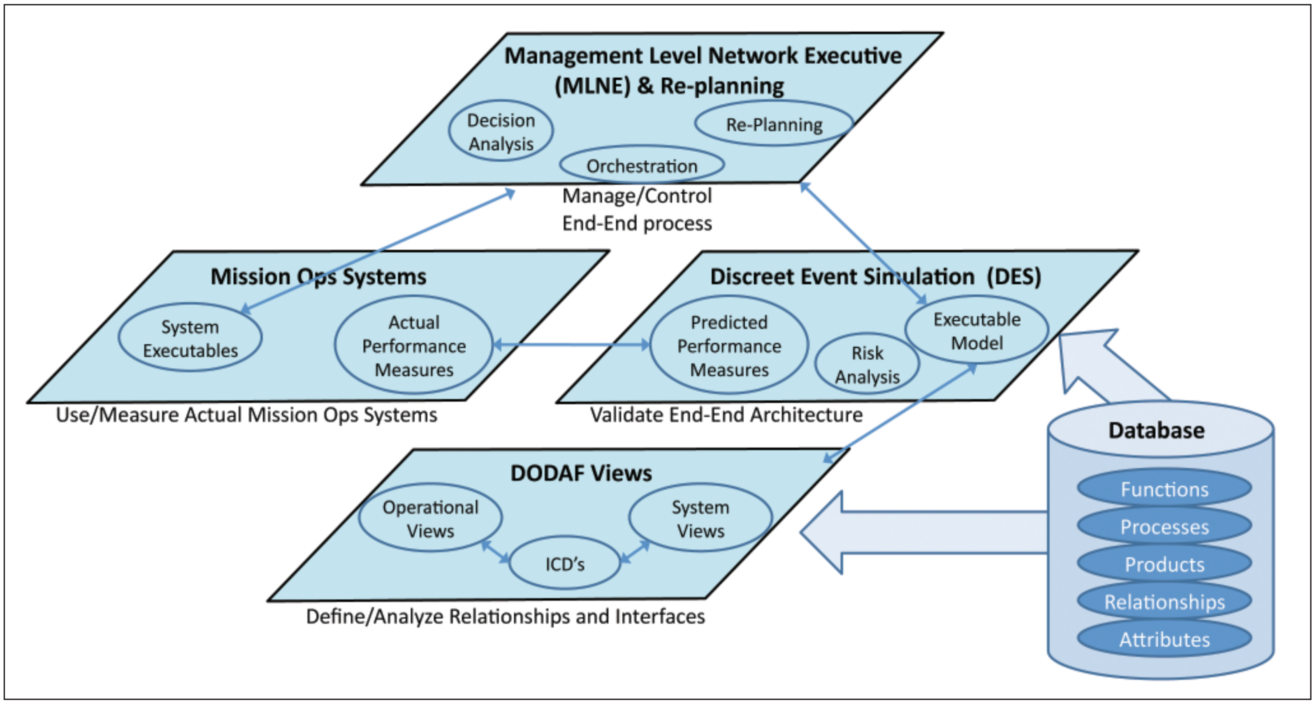

Fig. 1. *Multilayered architecture of the Mission Operations model.*

orchestrate the activities identified in the final system model, which is representative of the FPP design. The replanning entity allows for uncertainty management during operations. Such management might entail making changes to the original integrated workflow process as appropriate to address change requests that are either being produced externally or internally by the system based on the state of the system and its performance metrics. The re-planner does this dynamically and automatically.

Management interfaces with the manage/control layer to get the necessary information for making executive decisions. These decisions are then communicated with the operators and translated into commands for the flight system. Performance of the system is monitored, and the performance metrics are fed back into the database that in turn feeds the system models. The additional data are then used to update the existing data and make them more accurate.