ON MANAGEMENT OF VERY LARGE SCALE ENGINEERING PROJECTS

Ömer S. Benli, Information Systems Department, California State University, Long Beach, Long Beach, CA, 90840, 562-985-5918, obenli@csulb.edu
Khosrow Moshirvaziri, Information Systems Department, California State University, Long Beach, Long Beach, CA, 90840, 562-985-7965, moshir@csulb.edu

ABSTRACT[1]

Approaches to large scale engineering projects (LSEP) follow the paradigm established by the Manhattan project and the NASA's Space Exploration program. However, the following two assumptions are inherent to this paradigm. First, new technological innovations based upon a clear understanding of the basic principles that govern the entire system will be used. And secondly, thorough understanding of the goal of the project and its objectives and based upon these specifications, a design will be created and implemented. As a result, the mission will be accomplished. In this paper, we concentrate on an important module of a LSEP and offer a quantitative approach for the successful management of the system.

INTRODUCTION

With the advances in science and engineering, projects with ever-increasing complexity and scale are becoming commonplace. Unfortunately, their very nature defies the use of traditional project management tools. The remarkable developments in science and engineering at the dawn of 21st Century make many undertakings, hitherto unthinkable, technically possible. However, their full realizations are only possible if such projects are to be successfully completed within the allotted budget – temporal and financial. In no other area of modern technology, this is more evident than in very large-scale engineering projects. The significance of "modeling" for such systems is axiomatic. There are two types of mathematical models: descriptive and normative models. Among descriptive models, there are simulation models that describe how all or parts of the project will be realized over time as a function of parameters and policies. Normative models, or optimization models, on the other hand are developed to help managers make better decisions. "The construction of optimization models requires descriptive data and models as inputs" [2]. For example, one can simulate various policies in order to determine the best one among the ones that were tried.

This multi-phased approach, implied by the above discussion will be illustrated in the context of a recent project that authors participated. The project was sponsored by Northrop-Grumman Corporation for functional modeling of Orion Spacecraft operations for the purpose of quantitative risk analysis for project management. In the following, after presenting brief background information on the Orion Project, the proposed approach will be outlined. Then modeling and analyses are illustrated using hypothetical, but analogous, operations of the Orion Project.

BACKGROUND

In January 2004, President George W. Bush announced the *Vision for Space Exploration* for NASA. This vision directs NASA "to develop and execute a program aimed at returning humans to the moon, sending explorers on to Mars, and facilitating future exploration activities to *'destinations beyond'*."[2] The end goal of NASA's mission is to safely and affordably transport humans to and from *low earth*

---

[1] This is an abbreviated version of the full paper. The full paper is available from the authors upon request.
[2] "Report of the President's Commission on Implementation of United States Space Exploration Policy," June 2004.

orbit, from earth to moon and back to earth, and ultimately to and from Mars and beyond. The *Crew Exploration Vehicle* (CEV[3]), which will also be used to transfer the crew and cargo to and from (and evacuate the crew from) the International Space Station, will achieve this. Orion will succeed the space shuttle as NASA's primary vehicle for human space exploration. Orion's first flight with astronauts onboard is planned for no later than 2014 to the International Space Station. Its first flight to the moon is planned for no later than 2020.

Orion (CEV) is a reusable, Apollo-derived cone-shaped capsule launched atop the CLV. The CEV consists of a Crew Module (CM), a Service Module (SM), and a Launch Abort System (LAS). The vehicle uses a Low Impact Docking System (LIDS) for ISS and lunar missions. *The vehicle is reusable for up to 10 missions* and will land on land with a water landing as a backup. It will launch 25 metric tons to low-Earth orbit and serve as the long-term crew launch capability for the United States.[4]

ANALYSIS AND MODELING OF OPERATIONS

Design priorities for the Orion project are: (1) Safety and mission success, (2) Programmatic risk, (3) Extensibility and flexibility, and (4) Test and evaluation for the Orion project is the essence. Therefore, in addition to a thorough analysis and modeling of activities that make up all the essential operations, a quantitative risk analysis is imperative. The proposed approach in this study consists of four phases: (1) Enumerate the activities**,** with their complete duration estimates and resource requirements, (2) Construct the network diagram that depicts the inter-relationships among the activities, (3) Functional modeling of the operation such that the full relationships among activities and their resource requirements, and (4) Quantitatively analyze the risks based on the Monte Carlo simulation of the operation.

ACTIVITY LIST

This is a comprehensive list of all activities/tasks required in order to accomplish the required mission of the operation. The preparation steps are: (1) Itemizing tasks, (2) Estimating their durations, (3) Identifying the required expertise and equipment or other resources, and (4) Specifying any additional characteristics of the tasks.

ESTIMATING TASK DURATION

There are three types of tasks: (1) Activities with constant durations, (2) Activities with three time estimates for their durations, and (3) Activities with selection probabilities:

IDENTIFYING REQUIRED RESOURCES

The resource requirements for each task are estimated and are listed on the same spreadsheet as the other task related data.
Activity data List is used to construct a MS Project model.

NETWORK DIAGRAM, OUTPUT ANALYSIS , AND SIMULATION

Activity data List is used to construct a MS Project model. This section briefly reviews the statistical analysis done on the results of the Monte Carlo simulation [3] performed on the functional model. The ultimate aim of this analysis is to quantify the risks associated with the planned operations in the Orion project [1]. We simulated the sample functional model described in the previous section for 1,000 replications. These data can be considered as a sample of size 1,000 from an infinite

---

[3] NASA announced on August 22, 2006 that its new Crew Exploration Vehicle ("CEV") will be named "Orion". Henceforth, the term *Orion* will be used when referring to Crew Exploration Vehicle.
[4] Ibid.

population – all possible realizations of the operation in question. We will use this sample's statistics to estimates the population parameters.

POINT ESTIMATES

If one has to give a single number for the average time to complete the project it would be the sample mean, 160.40335 time units, in this example. (n = 1000, s = 55.512039)

CONFIDENCE INTERVAL

Clearly, the sample mean will not be exactly equal to the population mean. A better estimate would be an 'interval estimate'; that is, a confidence interval for the population mean:

One can be 95% confident that the population mean is in the interval:

$$\left[\bar{x} \pm t_{\nu=n-1,\alpha/2}\frac{s}{\sqrt{n}}\right] = \left[160.403 \pm 1.9623\frac{55.51}{\sqrt{1000}}\right] = [156.96, 163.85]$$

where the degrees of freedom, $\nu = n - 1$ = 1,000 – 1; the level of significance, α = 0.05; sample mean, $\bar{x} = 160.403$ and sample standard deviation, s = 55.51. That is, we can be 95% confident that the project duration will at most be 163.85 time units and at least be 156.96 time units.

PROBABILITY OF COMPLETION

If the assumptions of *Central Limit Theorem* are assumed to hold, we can state that

Prob{the project cannot be completed before 200 time units} = 0.2378, or
Prob{the project will be completed by 100 time units} = 0.1383.

PROBABILITY OF SUCCESS

If it is meaningful to define as 'success' when the project is completed by, say, 160 time units, then we can state that Prob{success} = 0.5520.

CONCLUDING REMARKS

This paper presented a process that integrates project management tools and techniques to enable proactive management across all phases of a large scale engineering project. Monte Carlo Simulation was also used as an improved methodology to quantify schedule risk and consequently to provide more reliable estimates of probability of successful project completion time.

REFERENCES

[1] Galway, L., "Quantitative Risk Analysis for Project Management: A Critical Review," WR-112-RC, Rand Corporation, February 2004.
[2] Shapiro, J. F., Modeling the Supply Chain, Duxbury, 2001.
[3] Armour, J. M., and Buffa, E. S., A Heuristic Algorithm and Simulation Approach, Management Science 9:294-309, 1963