OPERATIONS AND SUPPORT COST MODELING USING MARKOV CHAINS

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Systems for future missions will be selected with life cycle costs (LCC) as a primary evaluation criterion. This reflects the current realization that only systems which are considered affordable will be built in the future due to the national budget constraints. Such an environment calls for innovative cost modeling techniques which address all of the phases a space system goes through during its life cycle, namely; design and development, fabrication, operations & support and retirement.

A significant portion of the LCC for reusable systems are generated during the operations & support phase (O&S). Typically, O&S costs can account for 60 - 80% of the total LCC. Clearly, O&S costs are wholly determined or at least strongly influenced by decisions made during the design and development phases of the project. As a result, O&S costs need to be considered and estimated early in the conceptual phase. To be effective, an O&S cost estimating model needs to account for actual instead of the ideal processes by associating cost elements with probabilities.

One approach that may be suitable for O&S cost modeling is the use of the Markov Chain Process. Markov chains are an important method of probabilistic analysis for operations research analysts but they have rarely been used for life cycle cost analysis. This research effort evaluates the use of Markov Chains in LCC analysis by developing an O&S cost model for an hypothetical reusable space transportation vehicle (HSTV) and suggests further uses of the Markov Chain process as a design-aid tool.

The HSTV goes through a series of possible life cycle states such as launch preperations, launch attempt, ascent, orbit insertion, orbital operations, deorbit and landing. Once the HSTV is deployed, its utilization is cyclic, with essentially the same sequence of events repeated over and over until eventually it is lost in an acciedent or retired. In Markov Chain terminology ,these last two states are called absorbing or trapping states. Once the HSTV enters an absorbing state its life comes to an end and it will have to be replaced. Each of these possible states are identified and defined as a Markov State and represented by a point. A pictoral map of the HSTV life cycle process is constructed by connecting these points by arrows which represent the possible transitions and associated probabilities. These probabilities can be developed from reliability analysis of the HSTV or from operational considerations. In keeping with the ground rules of the Markov Process, the probability of going from any one state to another is assumed to be constant and dependent only on the particular state in question, independent of recent history and exegenous factors such as weather.

It follows by intiution that in the long run, the HSTV will eventually enter either one of the two possible absorbing states, being lost in an acciedent or retired from service. The number of successful launches before HSTV enters a trapping state represents the expected life of the vehicle. This number and the expected number of visits to each state before entering an

absorbing state is computed utilizing the mathematics of the Markov Chain theory. In the next step, the total O&S costs is established by multiplying these expected number of visits to each state by the cost associated with each state and summing them up over all the states. Cost per launch is then computed by dividing the total O&S cost by the expected number of successful launches.

The analysis of research results indicate realistically that, when the probability of a loss resulting from a mishap is considered, the O&S costs are considerably higher than an ideal success oriented path. Furthermore, the expected life of the HSTV is very sensitive to variations in the probability of entering a trapping state. This finding is significant in the sense that it suggests further uses of the Markov Chain analysis as a spacecraft design aid tool. The same approach can effectively be used in comparing different designs in terms of LCC and predicting the reliability requirements to meet a desired operation life. The information obtained from O&S cost analysis using Markov chains can also be used for resource and work planning at each state.

In conclusion, the Markov Chain Process is a powerful tool that can effectively be used in many life cycle cost analysis situations.