OPSMODEL, An On-Orbit Operations Simulation Modeling Tool for Space Station

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Abstract

AN operations analysis and planning tool (OPSMODEL) has been developed by Computer Sciences Corporation for NASA Langley Research Center to provide realistic modeling and simulation of on-orbit crew operations for a space station. The IBM PC compatible program produces a quantitative measure of the effectiveness of the on-orbit crew's activities under alternative space station designs, technologies, and operational policies. The OPSMODEL also supports engineering and cost analyses and operations planning activities. The simulation can be monitored on-line with the focus and level of detail selected by the user. Other outputs include engineering performance indicators, such as crew times and space station status, cost performance organized according to work breakdown structure, and various data products extracted from a time-tagged event log recorded during the simulation run.

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The OPSMODEL[1] is a flexible software tool that allows the user to model and simulate realistically the operational activities of a space station. Execution of activities can be prioritized and interruption of currently executing lower-priority activities is allowed. Its top-down modeling structure allows the user to control the level of complexity of model definition while limiting the effort expended for data base population to only what is necessary. The OPSMODEL has the capability for probabilistic modeling, utilizing both commonly used statistical functions as well as unique user-defined ones. The OPSMODEL has three major parts as shown in Fig. 1—a relational data base, a time-event simulator, and comprehensive data output.

The data base requires three groups of input data: 1) a description of the space station's physical configuration and a definition of resources (crew, equipment, and consumables) available; 2) a description of the operations/tasks to be executed in the simulation; and 3) the scheduling of these operations/tasks.

The simulator requires execution definition (start/stop times, number of repetitions, etc.) and selection of appropriate real-time monitoring options.

In addition to real-time simulation monitoring, three types of output data are available. The first data-output type shows engineering performance. Its output consists of execution data for each operation/task performed, crew time allocations for each operation/task (including crew idle times), space station status information (including equipment and consumable use), and other summary data.

The second output-data type shows cost-performance data organized according to resource, work breakdown structure (WBS), and task. Resources (crew, equipment, and consumables) used in the various operations/tasks can be assigned cost factors. A task can be assigned an appropriate charge number (WBS number), and all resources used in that task will be charged to that WBS number. When a simulation run is complete, the cost factors for each resource are multiplied by simulation-time use data, filed, and accumulated as costs in the WBS.

The third type of output is most useful to those interested in operations planning and analyses. These data are derived from a time-tagged event log that is recorded as the simulation is being run. This log can be viewed directly (via cathode ray tube or hardcopy), or specific data can be examined in various graphical or tabular outputs related to particular operations/tasks, crew members, equipments, or consumables.

The data required to define the work done on, in, and by the space station is described in terms of operations and tasks. A task is the smallest element of work used in OPSMODEL. Tasks may be connected to form operations. An operation may consist of only one task or as many tasks as necessary to define the work to be done.

A useful method of understanding the workings of operations and tasks is to think of each operation as having an "activation entity." This entity starts at the beginning of an operation, works its way through the consecutive tasks, and ends at operation completion. The simulator controls the movement of this entity and thereby controls the simulation and which tasks are active at any given time.

A task is the basic building block for all operations in OPSMODEL. The OPSMODEL sees a task in terms of a task diagram (TD) as shown in Fig. 2. The TD has two inputs: the external input where the activation entity normally enters and the internal input where the entity re-enters after having left via the internal output. The TD has three outputs: the normal output taken after the task is completed, the alternate output taken when conditional logic requires an alternate path, and the internal output used when the given work is expanded in terms of subtasks. Subtasks use the same TD template and allow more definition to the original task. Normally, the entity acquires resources to be used by the task, does the task work,

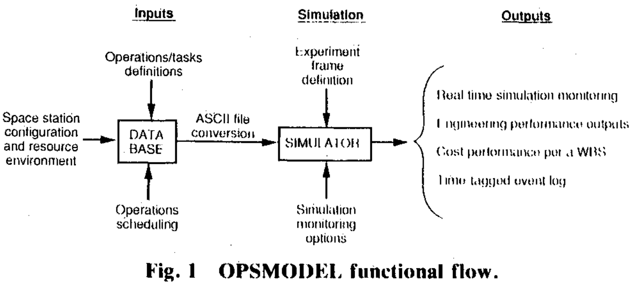

Fig. 1 OPSMODEL functional flow.

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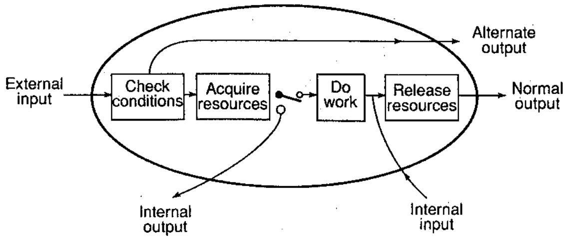

Fig. 2 Task diagram.

releases the resources, and exits. If subtasks are present, the switch shown in Fig. 2 is switched to the internal output, the subtasks are performed, and the entity returns to the main task via the internal input. The entity then releases the resources it acquired at the beginning of the task and exits. The number of levels of subtasks is not constrained.

The versatility of modeling capabilities represented in OPSMODEL is large and ranges from the straightforward to the not so obvious (but still easy to implement). Representative examples that seem particularly useful include the following:

1) Daily crew activities: for example, lunch may be modeled as an operation with individual tasks representing preparation, eating, and clean-up. The tasks, along with pertinent resource and scheduling information, are easily entered into the data base.

2) Space station environment: recurrent phenomena such as orbital day/night cycles can be modeled as an operation. Other tasks which conditionally execute on these phenomena may then be defined.

3) Equipment failure and repair, emergencies: failures may be modeled by scheduling them to occur at predetermined times (either fixed or statistically determined) based on the mean-time-between-failure. In addition, the time duration of the failure task is analogous to the mean-time-to-repair (and can also be defined statistically). Other emergencies can similarly be modeled.

4) Probabilistic modeling: repetitive tasks can be given their own appropriate initiation and duration distributions for more realistic simulation.

5) Crew variables: the effects of crew definition variations on a simulation can be easily analyzed by data substitution in the data base. Examples would be the effects of crew size, crew skill mix, and one- vs two-shift operation.

6) Space station configuration: alternative configurations and layouts can similarly be analyzed by data base substitution.

7) Job scheduling: the jobs or operations to be performed by the astronauts could be efficiently scheduled by using the priority capability of OPSMODEL. A longest-duration-time algorithm has been implemented by giving the longer-duration jobs the higher priorities. This has the effect of minimum crew idle time.

8) Consumable generation: consumables (such as power) may also be generated by use of a negative consumable rate. This capability allows the time-dependent tracking of such things as currently available electrical energy or the station thermal balance.

9) Inventory modeling: counters attached to tasks are able to establish initial inventory levels as well as to increment and to decrement.

10) Alternate technology/alternate operational scenarios, etc.: these and a number of other comparison analyses (hardware technology upgrades, extravehicular activity vs teleoperation, etc.) can be implemented by substitution of appropriate sections of the data base.

Since delivery, the OPSMODEL program has been extensively exercised and tested by the author with both specialized (specific function oriented) and "typical" densely populated data bases. Typical applications, as listed above, have been defined and tested, while user-friendliness and efficiency have been enhanced. In addition, conditional logic capabilities have been expanded and graphical output capabilities have been added.

The OPSMODEL program will effectively provide a state-of-the-art operations simulation laboratory where user-defined and scheduled operations execute within user-defined resource and priority constraints.

References

[1]Davis, W. T. and Wright, R. L., "OPSMODEL, An On-Orbit Operations Simulation Modeling Tool for Space Station," AIAA/SOLE Paper 88-4732, Oct. 1988, pp. 94–103.

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