A Format for the Interchange of Scheduling Models

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KEY WORDS AND PHRASES

Activity modeling, activity scheduling, model interchange, space station.

INTRODUCTION

In recent years a variety of space-activity schedulers have been developed within the aerospace community. Space-activity schedulers are characterized by their need to handle large numbers of activities which are time-window constrained and make high demands on many scarce resources, but are minimally constrained by predecessor/successor requirements or critical paths.

Two needs to exchange data between these schedulers have materialized. First, there is significant interest in comparing and evaluating the different scheduling engines to ensure that the best technology is applied to each scheduling endeavor. Second, there is a developing requirement to divide a single scheduling task among different sites, each using a different scheduler. In fact, the scheduling task for International Space Station Alpha (ISSA) will be distributed between NASA centers and among the international partners. The format used to interchange scheduling data for ISSA will likely use a growth version of the format discussed in this paper.

The model interchange format (or MIF, pronounced as one syllable) discussed in this paper is a robust solution to the need to interchange scheduling requirements for space activities. It is highly extensible, human-readable, and can be generated or edited with common text editors. It also serves well the need to support a "benchmark" data case which can be delivered on any computer platform.

FILE FORMAT

The data which is interchanged via the model interchange format is contained in a data set or file. When the data is stored in a file on a platform which supports a file extension as part of the file name, the extension ".MIF" should be used.

A MIF file is arranged in lines or records. Each record contains *a single* keyword and may contain data values. Keywords are surrounded by vertical bars. They are case sensitive and should not contain characters, such as spaces or commas, which might be used as input delimiters in common user interfaces.

The information is organized as a hierarchy in parent, child, sibling relationships. No keyword can be the same as an ancestor or the sibling of an ancestor. Therefore, on any record, a keyword which is a child, sibling, ancestor, or sibling of an ancestor of the keyword of the previous record may be listed without ambiguity. But, while descending the hierarchy, ancestral keywords can*not* be skipped. To obtain the full meaning of the data on a record, the keyword on the record and all keywords (records) in its ancestry must be considered. The order of the records in a file is usually significant; arbitrary reordering of the information is not allowed.

The file format limits the use of vertical bars to keywords and disallows the use of the backslash (\) character throughout. Identifiers or names cannot contain a comma, parenthesis, or space. The file format also specifies formats for the following data types: single integer, multiple integers including range-of-integers, real numbers, time expressions, date expressions, and character strings.

FILE CONTENTS

At the time of this writing, over 200 keywords have been defined in three independent hierarchy structures: a data set description hierarchy, a mission model hierarchy, and an activity model hierarchy. Figure 1 shows the logical organization of the file, with hierarchies shown for the data set description, mission model, and several activity models.

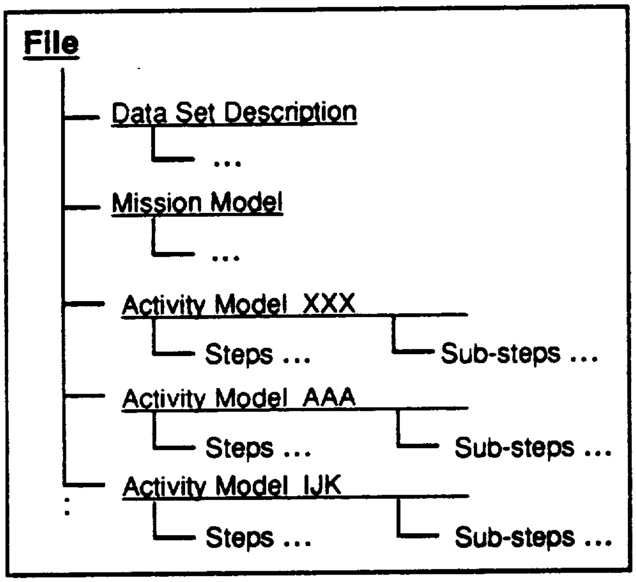


Figure 1. MIF File Organization.

Data Set Description

The data set description tells what is on the file, its source, and related data.

Mission Model

The mission model describes the availabilities of the resources for a particular scheduling task. The following items are included in the mission model:

- Identifiers and descriptive data.
- Resource availability profiles (including resource envelope definitions).
- Equipment reconfiguration data and crew relocation times.
- Pre-scheduled crew timeline and duty cycle data.

Activity Models

Activity models are used to describe the payloads or experiments to be scheduled. Each payload or experiment requires one or more activity models; for complex payloads, an activity model is usually included for each functional objective.

An activity model is the collection of constraint definitions describing a payload or experiment. Some of the constraints apply to the model as a whole, while others only apply to the model partitions, known as steps and sub-steps.

The smallest required, fully functioning, clearly delineated partition of an activity model is called a step. The steps of an activity model describe most of the resource constraints of the model. Each activity model in a MIF file must have at least one step.

The optional partition of an activity model which supports the execution of one or more steps is called a sub-step. Two classes of sub-steps are currently defined: crew monitoring sub-steps and resource carry-through sub-steps.

An execution of an activity model is called a performance. The performance of an activity model is generally considered to consist of the execution of the model's steps and sub-steps. A model may be performed multiple times to collect data. Each performance may contain a different set of steps and sub-steps, or they may be arranged differently when compared to other performances of the same model. Step-based schedulers usually require that each performance contain at least one step.

The model/step/sub-step structure for representing requirements was chosen because it was judged to be more robust than other representations. This representation observes well the axiom that models should exhibit high fidelity and flexibility; high fidelity means that an observer can correlate the model to the actual activity; high flexibility means that the model can represent the scheduling flexibility of the actual activity. The chosen representation also supports interchanges with schedulers which use models with requirement profiles attached directly to the model; in the model interchange format, a one-step model with requirement profiles on that step is used.

AVAILABILITY

Currently the Mission Planning Division at the Marshall Space Flight Center is the keeper of this format. As stated earlier, a growth version of this format is expected to be used for interchanging scheduling data for International Space Station Alpha (ISSA). The current definition may be superseded by the ISSA definition, and the ISSA configuration control function may become the keeper of this format.

Those wishing to have the format extended should contact the authors of this paper.

Documentation

The complete model interchange format is available in printed form, or electronically in PostScript, Bookreader, and possibly World View formats. Documentation can also be accessed on the World Wide Web via Mosaic.

Sample Data Cases

Sample files containing the subset of the defined format currently used by Marshall Space Flight Center are available for several Spacelab missions and some ISSA data cases.

Software Requirements

Implementers of software which reads a MIF file should allow for extensions of the format. Since at some future date new keywords may be defined, the software should contain code to ignore unrecognizable keywords. They must also develop mapping code to convert data in the MIF representation to their internal representation.

Implementers of software which writes a MIF file must develop mapping code to translate their data to the MIF representation.

SAMPLE MIF DATA

Figure 2 shows part of a two-step activity model with variable separations and durations. This figure also shows a sub-step (its keyword is `|-step|`). The sub-step could also have been positioned before step 1 or after step 2. Representing the requirements as two steps and a sub-step is considered a high fidelity representation because it closely matches the usual description of the activity. The model has high flexibility because it captures the variable step separation and duration, and the choice of crewmembers for step 2. As shown, the model does not require that high power be available immediately before shadow. The sub-step would not be scheduled whenever the separation between

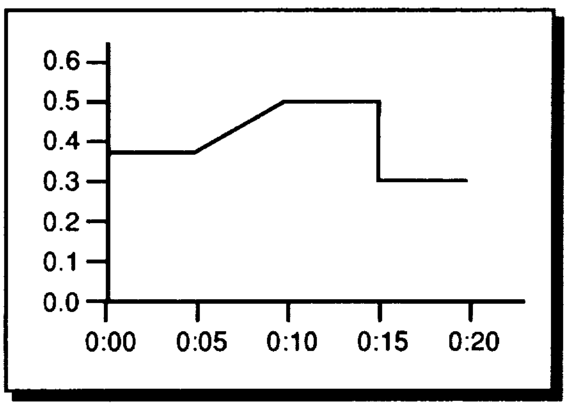
```
|Model| SEPAC-1
    |Comment| Beam firing (low power)
    |Partner| USA
    |step| 1
        |description| Capacitor charge
        |science_value| 0
        |duration| 0:15:00
        |nondepletable| POWER
            |profile| 2.750
        |carry-through|
            |sub-step| trickle
    |-step| trickle
        |-description| capacitor trickle charge
        |-nondepletable| POWER
            |-profile| 0.128
    |step| 2
        |description| Beam Firing (level 1)
        |separation|
            |min| 0:00:00
            |max| 0:30:00
        |duration|
            |min| 0:10:00
            |max| 0:20:00
            |preferred| 0:20:00
        |science_value| 4
        |crewlist|
            |type| FULLTIME
            |pick| 1
            |crewmember| PS1
            |crewmember| PS2
            |at_location| MODULE
        |crewlist|
            |type| FULLTIME
            |pick| 1
            |crewmember| Commander
            |at_location| MID-DECK
        |intersected_opp| SHADOW
        |intersected_opp| K-band
        |nondepletable| POWER
            |profile| 0.500
```

Figure 2. A Model with Variable Durations.

steps 1 and 2 is zero.

Figure 3 presents part of a one-step activity model with a power profile (shown in inset).

```
|Model| SEPAC/co
    |Comment| Check out hardware
    |step| 1
        |duration|  0:20:00
        |nondepletable| POWER
            |profile|
                |time|        0:00:00
                |usage|         0.381
                |time|        0:05:00
                |usage|
                    |initial|   0.381
                    |final|        0.50
                |time|        0:10:00
                |usage|         0.50
                |time|        0:15:00
                |usage|         0.30
```



POWER Requirement Profile

Figure 3. A Model with a Power Profile.

This type of model would be used in schedulers which use activity models with requirement profiles attached directly to the model. The current format limits profiles to constant values, ramps, and step functions.

SUMMARY

The four significant requirements that drove the formulation of the model interchange format were that it must be universal, extensible, portable, and human-readable. Since this format was developed chiefly for the interchange of data, rather than for the storage and manipulation of data within schedulers, these requirements were deemed to be more important than efficiency.

Universality

A format was needed which could be used by all space-activity schedulers. This format provides for all known constraints and requirements which affect the scheduling of space activities. The section entitled "File Contents" in this paper describes the current contents.

Extensibility

It was necessary that the format be one which can evolve as new capabilities are added to existing schedulers and as new schedulers are developed. This format may be extended by adding to existing hierarchies; i.e., by defining new children or siblings at any level. Entirely new hierarchies may also be defined; this is equivalent to defining siblings of the highest level in the current hierarchy.

Portability

Since currently available schedulers are on different platforms, a format which could be read or written on any platform was needed. To this end, the information is stored in a MIF file as ASCII characters only and is line- or record-oriented. A benefit of this characteristic is that the file can be edited with common text editors.

Human-readable

A person can easily read a MIF file or use a text editor to create/edit one by virtue of the following attributes:

- The syntax is simple. There are a limited number of rules and special characters.
- A cascading outline hierarchy is used. Each entry in the hierarchy resides on a separate line with no other keywords. Ancestry keywords are not necessarily repeated; the common conventions for outline presentation are followed.
- The format is free. Virtually nothing within a line is positional. The user can indent as desired to improve readability.