FLEXIBLE ENVELOPE REQUEST NOTATION
(FERN)

December 13, 1990
David Zoch
David LaVallee
Stuart Weinstein

Agenda

- Background
- FERN Language Concepts
- FERN Syntax Examples
Scheduling Application

- Science users send requests to the Resource Scheduling System.
- Requests are requirements for planned instrument operations and are written in FERN.
- The Resource Scheduling System, which may reside in a POCC, processes the requests and generates a schedule.
- The schedule specifies the timeline of user activities and is distributed to the science users.

Motivation for FERN

- Science users must represent their resource requirements and constraint relationships in a format that can be interpreted by computers.
- If their initial resource requests cannot be satisfied, science users need to propose reduced resource amounts or alternative experiments for their instrument operations. Thus, some of the science user requests may be flexible and complex rather than simple.
- FERN uses a language format. For example, "TAPE_DUMP for 5 minutes to 10 minutes" is more user-friendly than "TAPE_DUMP,5,10." This format allows users to state their requirements in a more direct and natural manner.
Characteristics of FERN

- **ROBUST**
  - Supports a variety of user resource requirements and constraints.
  - Supports alternative resource amounts and requests.
  - Supports repetitive requests ("generic requests") based on orbital events rather than specific start times.

- **READABLE**
  - Keyword based, not positional. For example, avoids "ROB1,2-4,60,200-300."

- **FLEXIBLE**
  - Time durations and relaxable constraints

- **OBJECT-ORIENTED**
  - Data abstraction
  - Reusable data objects

Types of Information Needed in Requests

- *Flexible* resource requirements
- *Flexible* request durations
- *Flexible* experiment timing / coordination requirements between activities
- Scheduling information for repetitive activities
- *Alternative* activities
- Relative importance of each requirement
Where Information is stored in Requests

REQUEST FOR RESOURCES

- GENERIC REQUEST
  - Activity Sequencing
  - Repetition
  - Conflict Resolution Rules

ACTIVITY
  - Step Durations
  - Priority
  - Step Sequencing

STEP
  - Resources
  - Constraints

Activity1
  - Step1
  - Step2
  - Step3

Activity2
  - Step4
  - Step3

FERN Structures

GENERIC REQUEST
- Pattern of replication of activities
- Alternative activities
- Rules

ACTIVITY
- Sequence of steps that comprise the activity
- Duration of steps
- Constraints common to whole activity
- Defined in database, then referenced by name in GENERIC REQUEST

STEP
- Amounts of resources
- Constraints
- Defined in database, then referenced by name in ACTIVITIES
RESOURCES
- Support user operations.
- Are represented as scalars that vary over time.

CONSTRAINTS
- Restrict the times when a request can be scheduled.
- Are specified with respect to timegraphs, activities, steps, or other requests.

TIMEGRAPHS
- Are used to specify time windows, view periods, preferable scheduling times, spacecraft events, calendar events, etc.

Generic Request

Generic GENERIC_NAME is
3 to AS MANY AS POSSIBLE activities per Sun_in_view
With default min start time separation 5 minutes,
With default max start time separation 10 minutes,
With summed duration 4 hours, ≈ sum of multiple activity durations is 4 hours
With priority 2,
With strategy Maximizing_Separation
Schedule
ACTIVITY1 and ACTIVITY2
Or schedule
ACTIVITY3
Or schedule
ACTIVITY4 With min start time separation 4 minutes
End generic
Activity

Activity *ACTIVITY_NAME* is
Steps
  *STEP1* for 1 to 8 minutes,
  *idle STEP2* for 2 to 5 minutes,
  *STEP3* for 5 minutes,
  *interruptable STEP4* for AS LONG AS POSSIBLE,
  *STEP5* for 5 minutes
With activity duration 30 minutes
End activity

Interruptable Step - resources of step can be re-allocated without disrupting activity.

Idle Step - same as interruptable, but not displayed on timeline. Used to represent idle periods.

Step

Step *STEP_NAME* is
Resources
  *INSTRUMENT_X*,
  *POWER* 5 watts,
  *TDRSS_SA 1*,
  ...
Constraints
  Occurs entirely during *ORBIT_DAYLIGHT*,
  Starts at the same time as *ACTIVITY_X*,
  ...
End step
Resources

• Initial amount may vary over time in discrete steps

• Pooled resources contain equivalent or nearly equivalent items:
  - TDRSS is (TDRSS_E, TDRSS_W)
  - Crew member is (commander, pilot, mission_specialist)
  - Redundant equipment is (line_recorder_1, line_recorder_2)

• Some resources are available at different times to different users (e.g., TDRS)

• Resources may be either durable or consumable

Pooled Resources

Resource \( TDRSS\_SA \) is
(Forever \( (TDRSS\_E\_SA1, TDRSS\_E\_SA2, TDRSS\_W\_SA1, TDRSS\_W\_SA2) \))
End resource

TDRSS_SA Allocation

Even though some TDRSS_SA is available at every point, no single antenna is continuously available. Thus, a request for 50 minutes of TDRSS_SA is NOT satisfied.
Resource Availability for Pooled Resources

Some resources are available at different times to different users.

For example, TDRSS communication resources are available at different times to different satellites, depending on the position of the satellite with respect to TDRSS.

Step DATA_LINK is
Resources
TDRSS_E
Constraints
Occurs entirely during TDRSS_IN_VIEW
End step

TDRSS_E
TDRSS_IN_VIEW
Availability

Expressive Notation

Supports non-specific durations:

VIEW_STAR_STEP for AS LONG AS POSSIBLE
RECALIB_STEP for 2 to 8 minutes

Supports flexible requests where the resource amounts and duration of the request are selected by alternative relaxation levels. This capability allows the scheduling algorithm to reduce resource amounts or shorten the duration of the request in order to fit the request on the schedule:

RESOURCE1 15 units,
RESOURCE2 (25 units, 23 units AT RELAXATION 4,
19 units AT RELAXATION 8,
15 units AT RELAXATION 12)

STEP1 for (30 minutes, 28 to 30 minutes AT RELAXATION 5,
25 to 30 minutes AT RELAXATION 15)
Temporal Constraints

- Temporal Constraints specify when a request can be scheduled with respect to:
  - Calendar Events, Orbital Events, Requests, or User Defined Events
- Allow for precise activity sequencing and coordinated activity dependencies.
- Sample temporal relationships between request A and object B are:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>A</td>
<td>Occurs after B</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>Ends 5 minutes after the start of B</td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td>Occurs right after B</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>Overlaps all of B</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>Does not overlap B</td>
</tr>
</tbody>
</table>

Profiles

Things that vary over time

FOREVER

CREATE

CREATE PERIODIC

INVERT

UNION

INTERSECT

MODIFY
  - With start earlier by 5,
  - With end later by 5

SELECT 1,3,4
Time Formats

Representation of Absolute Time:
- 1990/120/09:00:15.12 April 30, 1990, 9:00:15.12 am
- 1990/120-09:00:15.12 April 30, 1990, 9:00:15.12 am
- 1990/4/30-09:00:15.12 April 30, 1990, 9:00:15.12 am

Representation of Relative Time:
- 3/2:30 3 days, 2 hours, and 30 minutes
- 2.5 2 hours, 30 minutes
- 2.5 hours 2 hours, 30 minutes
- :24.25 24 minutes, 15 seconds
- 24.25 minutes 24 minutes, 15 seconds

Changes to FERN

New FERN
- UIL like - keywords
- Generic repetition by iteration or user-defined windows
- Direct support of alternatives
- Flexible duration
- Pooled resources
- Database of steps

Old FERN
- LISP like - ()
- Generic repetition by iteration
- Alternatives by mutual exclusion
- Fixed duration only
- No pooled resources
- Unnamed phases
Sample FERN Requests

Support the following features:
-- Temporal relationships between steps or activities
-- Maximum activity length to limit step delays
-- Alternative requests
-- Idle resource usage between steps of the same activity
-- Flexible request durations
-- Relaxable constraints
-- Event driven planning/scheduling concepts
-- ESP and UIL time formats
-- Step oriented (generics -> activities -> steps)
-- Min and max delays between steps and activities
-- User priorities

SEAS
Systems, Engineering, and Analysis Support

Temporal Relationship between Two Steps

Problem: The steps ERBS_TR_DUMP and ERBS_RANGING occur concurrently when command uplink and telemetry downlink are available (coherent transponder mode). This example shows how to specify relationships between steps by using a constraint expression.

Step ERBS_TR_DUMP is
  Resources
    TDRSS_I_CHANNEL_FORWARD_LINK, -- mode 1.0 kbps
    TDRSS_I_CHANNEL_RETURN_LINK, -- mode 1.6 kbps
    TDRSS_Q_CHANNEL_RETURN_LINK -- mode 32 kbps
  End step

Step ERBS_RANGING is
  Resource
    TWO_WAY_RANGING_AND_DOPPLER 1,
  Constraint
    Occurs entirely during ERBS_TR_DUMP
  End step
Maximum Activity Length to Limit Step Delays

Problem: The transition between steps is flexible and does not need to occur at a specific time. Switching from command uplink only mode to command uplink and telemetry downlink mode may begin from 5 to 7.5 minutes after the ERBS activity start time.

Activity **ERBS_NORMAL_CASE** is
Steps
- **ERBS_CMD_LOAD_AND_DOPPLER** for 5 minutes to 7.5 minutes,
- **ERBS_CMD_LOAD** for 2.5 minutes to 5 minutes,
- **ERBS_TR_DUMP_AND_RANGING** for 13 minutes,
- **ERBS_TR_DUMP** for 10 minutes
With activity duration for 33 minutes
Constraint
Starts during **ERBS_WINDOW**
End activity

System, Engineering, and Analysis Support

Alternative Requests

Problem: In some cases, all of the activities (instances) belonging to a generic request cannot be scheduled. Alternative requests are backup requests which tell the scheduling system how to resolve conflicts. In this example, the last alternative request applies only to those activities (instances) that remain unscheduled after the nominal request and first alternative request were processed.

Generic **ERBS_SUPPORT** is
1 activity per **EVERY_TWO_ERBS_ORBITS**
Schedule
- schedule nominal first
  **ERBS_NORMAL_CASE**
Or schedule
- move ranging step to try to resolve resource conflict
  **ERBS_RETURN** and **ERBS_SMALL_WINDOW_TRACKING**
Or schedule
- if one of the ERBS activities cannot be scheduled, place it within the next 3 orbits
  **ERBS_BIG_WINDOW_RETURN** and **ERBS_BIG_WINDOW_TRACKING**
End generic

System, Engineering, and Analysis Support
Temporal Relationship between Two Activities

Problem: The CLAES instrument normally views for three days on and three days off. However, during a spacecraft yaw maneuver, the science user wants to interrupt the normal view activity to close the instrument's aperture door. The normal view activity resumes after the spacecraft yaw maneuver.

Activity CLAES_CLOSED_DOOR_VIEW_ACT is
Steps
CLAES_CLOSE_APERATURE_STEP for 1 minute,
CLAES_DOOR_CLOSED_VIEW_STEP for as long as possible,
CLAES_OPEN_APERATURE_STEP for 1 minute,

Constraints
Overlaps exactly UARS_YAW_MANEUVER
Occurs entirely during CLAES_NORMAL_VIEW_ACT

End activity

Idle Resource Usage between Steps

Problem: The HALOE instrument alternately views the sunrise and sunset. In between, it is stowed. The idle step is used to maintain the minimum resources required for stowing between viewing.

Activity HALOE_NORMAL_ACT is
Steps
HALOE_SUNRISEVIEW_STEP for 15 minutes,
HALOE_SUNRISE_SLEW_TO_STOW_STEP for 20 seconds,
Idle HALOE_STOW_STEP for as long as possible - limited to about 25 minutes
HALOE_SUNSET_VIEW_STEP for 15 minutes,
HALOE_SUNSET_SLEW_TO_STOW_STEP for 15 seconds,
Idle HALOE_STOW_STEP for as long as possible - for remainder of orbit

End activity