Automated Derivation of Complex System Constraints from User Requirements

Mark Foshee, CSC
Kim Muery, NASA, Marshall Space Flight Center
Angela Marsh, NASA, Marshall Space Flight Center
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Background

- The Payload Operations Integration Center (POIC) located at the Marshall Space Flight Center has the responsibility of integrating US payload science requirements for the International Space Station (ISS).

- All payload operations must request ISS system resources so that the resource usage will be included in the ISS on-board execution timelines. The scheduling of resources and building of the timeline is performed using the Consolidated Planning System (CPS). The ISS resources are quite complex due to the large number of components that must be accounted for.

- The planners at the POIC simplify the process for Payload Developers (PD) by providing the PDs with an application that has the basic functionality PDs need as well as list of simplified resources in the User Requirements Collection (URC) application.

- The planners maintained a mapping of the URC resources to the CPS resources. The process of manually converting PD’s science requirements from a simplified representation to a more complex CPS representation is a time-consuming and tedious process.

- THE GOAL: To provide a software solution to allow the planners to build a mapping of the complex CPS constraints to the basic URC constraints and automatically convert the PD’s requirements into systems requirements during export to CPS.
Constraints

- The term constraint is used to represent both resources and conditions.
  - Resources, such as power, have an availability of some amount over time.
  - Conditions have availabilities defined in binary terms and may be used concurrently by an unlimited number of activities. (e.g., TDRS availability)
  - Constraint types include general, condition, video, data, crew, water/Gas, photo, power/Thermal, vacuum, and commanding

- Two Different Constraints
  - URC constraints
    - Defined by the payload planner in the User Requirements Integration (URI) and are highly simplified
    - Payload Developers select the URC constraints in User Requirements Collection (URC) while building his activities.
  - CPS constraints
    - Defined by the planning community in the CPS and are used during timeline development.
Constraint Representations

Complex System Constraint

- Video Downlink in Real-Time
  - ISS DATA TOTAL – DIGITAL TOTAL
  - ISS DATA Video – Video System Total
  - ISS DATA Video – VSUx
  - ISS Data Video – HRFM VIDEO PORT
  - US SEG VIDEO EQUIP – LAB CAMCORDER
  - US SEGMENT DATA – RACK LAx video port
  - ISS TDRS – ALL KU AVAIL

Simplified URC Constraint
Activities

• Activities are typically developed by the payload developer to model a task to be performed (e.g., payload startup, experiment execution). Activities define
  • the applied constraints, i.e., resources quantities, durations and related attributes
  • the required duration of the activity
  • location of the activity
  • procedures to be executed

Sequences

• Sequences represent a collection of dependent tasks to be performed as a unit to meet a science objective.
• Sequences define the temporal relationships between the members of the sequence and the execution windows.
• Sequence members may be activities or other sequences.
Activity

Applied Constraint

Attribute selections

Time Intervals
Sequence
Increments and Topologies

• Increments
  – Increments are operational time periods defined by the beginning and ending of a crew rotation. When new crew members begin to operate the ISS, a new increment begins and the prior increment ends.

• Topologies
  – A URI topology is used to model the ISS configuration by modeling the payload rack locations for the purpose of assigning location specific ISS constraints.
  – Topologies can change due to new payloads, terminated payloads, or system re-configurations.
  – Topologies are assigned to an increment and be assigned to many increments.
  – Topologies in URI are defined by creating segments (e.g., USOS) and assigning rack locations to those segments.
  – Payload aliases are assigned to the topology locations.
    • Payload aliases allow the a convenient way to assign location, crew, and CPS specific attributes to a group of activities.
Topology

Segment

Locations

Payloads Aliases

Local Constraints
Constraint Mapping

Mappings of CPS Constraints to URC Constraint Attributes
Constraint Mappings

- Constraint mappings are relationships (many-to-many) defined between URC constraints and CPS constraints.
- Constraint mappings are assigned to a specific topology.
- Constraint mappings can define a linear relationship to be applied on export to the URC resource requirement to determine the appropriate amount of the CPS resource. This capability is useful in cases where the desired CPS constraint has different units of measure that the URC constraint.
- Constraint mappings can be one of three types:
  - General - applied to the activity regardless of location
  - Location specific – must be resolved using the location of the activity and the CPS constraints that are assigned to that location
  - Crew – a crew member aboard the ISS. Crew assignments are defined in the payload alias
Timeline

• Timeline is the result of scheduling the activities and sequences in a manner which results in a plan for conflict-free execution of required events and ensures availability of required resources for each activity.

• In a timeline, each activity and sequence is assigned a fixed start time and stop time.

• Timelines are developed in CPS
Model the ISS topology for an increment

Import CPS constraints into URC

Develop simplified constraints in URC

Create activities and sequences

Develop increment specific attributes

Using the topology, map URC constraints to CPS constraints

Planners assign payload aliases and define CPS specific attributes

Submit completed activities and sequences to the POIC

Planners export URC activities and sequences to CPS

- Export uses the increment to gather the applicable constraint mappings and increment-specific data
- Export uses the constraint mappings to resolve the URC constraints into CPS constraints for each activity

Payload Developers

Operations Concept

Planners

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Payload Planning System Overview

- Data System Routing and Configuration (DSRC)
- User Requirements Collection (URC)
- Consolidated Planning System (CPS)
- Reports
- User Requirements Integration (URI)
- Export
- CPS Loader
- CPS Database
- PPS Database

Diagram shows the integration and flow of data among the different systems and databases.
User Requirements Collection

- Used by PDs for the following tasks:
  - Model Activities
  - Model Sequences
  - Submit requirements to the POIC for scheduling
  - Generate reports
User Requirements Integration

- Used by Planners and Planners for the following tasks:
  - Model constraints
  - Model topologies
  - Setup Increment-specific data
  - Create constraint mappings
  - Manage and access PD’s activities and sequences
  - Export to CPS
  - Generate reports
Consolidated Planning System

- Used by Planners and Planners to schedule payload activities and sequences
- Developed by JSC
Export Function

- Exports activities, sequences, and resources to CPS
- Uses the constraint mappings to resolve the URC constraints into CPS constraints for each activity
- Uses the increment to gather the applicable constraint mappings and increment-specific data
Conclusions

• Using an automated process to convert payload developer science requirements from a simplified representation to a more complex representation required in the Consolidated Planning System (CPS)
  – Increases operational efficiency
  – Ensures reliable results
  – Provides payload developers a logical approach to modeling requirements.
  – Allows minimum changes by the payload developers to the activities and sequences when system re-configurations are made

• Analyzing operations processes can reveal innovative solutions that can produce cost, efficiency, and reliability benefits.

• Q & A