INCREASING HUMAN SPACEFLIGHT CAPABILITIES: DEMONSTRATION OF CREW AUTONOMY THROUGH SELF-SCHEDULING ONBOARD INTERNATIONAL SPACE STATION

J. J. MARQUEZ¹, S. HILLENIUS¹, & M. HEALY²
¹NASA AMES & ²SGT, INC. (NASA JOHNSON)
JESSICA.J.MARQUEZ@NASA.GOV
TODAY’S TALK

Why enable crew self-scheduling?

Crew autonomy in the context of ISS environment

Self-Scheduling Software: Playbook

CAST testing onboard ISS

Technical & operational lessons learned
TOWARDS EARTH-INDEPENDENCE

Increasing Communication Latency

EARTH RELIANT  PROVING GROUND  EARTH INDEPENDENT

CREW AUTONOMY THROUGH SELF-SCHEDULING
CREW AUTONOMY: SELF-SCHEDULING

**BENEFITS**
- Mitigates effects of communication latency, intermittent communication, and limited bandwidth.
- Enables crew to contribute their insight how to best manage schedule.
- Minimizes idle time waiting for Mission Control responses.

**CHALLENGES**
- Different concept of operations that requires new protocols.
- Do not want to overwhelm astronauts who are not expert mission planners.
- Still need to ensure and retain constraint-abiding plans and schedules.
Flight Operations Directorate (FOD) believes that future human exploration efforts will require daily operations between ground and crew to evolve from the low-Earth orbit mission environment.

New Concept of Operations (ConOp): crew autonomy to effectively and efficiently schedule and execute astronaut’s next day.

NASA Johnson Space Center and NASA Ames Research Center collaborated to investigate new ConOp onboard International Space Station (ISS).
ISS OPERATIONAL ENVIRONMENT

Numerous & various types of activities
Assignment of highly complex activities
Six crew member schedules to coordinate

Complex scheduling and planning requirements
Numerous constraints and resource limitations
Cooperating with various international partners
Tightly scheduled weekly timelines.

Meet operational requirements from program, crew, payloads, and spacecraft.

ISS Program does not operate under the crew autonomy ConOp.

HOW CAN CREW SELF-SCHEDULE ONBOARD ISS?
CAST EXECUTION

- Coordinate with ISS flight controller teams
- Deploy software tool for crew self-scheduling
- Execute CAST exercises onboard ISS
- Collect data and debrief from astronaut
# COORDINATING CAST EXERCISES

Five exercises, increasing the crew’s autonomy
Exercises occur on full, nominal, crew days
Exercise days carefully chosen to capture future mission realism, minimize current mission risks, and maximize investigation return.

<table>
<thead>
<tr>
<th>Familiarization &amp; Training</th>
<th>Practice</th>
<th>Self-Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise #1</td>
<td>Exercise #2</td>
<td>Exercise #3</td>
</tr>
</tbody>
</table>

- Planning Familiarization (Fake day)
- Execution Familiarization (Prepared Plan)
- Schedule Afternoon (Limited Planning)

| | Self-Schedule | Execute Self-Schedule | Self-Schedule | Execute Self-Schedule |
| | | | | |
| | Self-Schedule | | | |
| | Execute Self-Schedule | | | |
| | Self-Schedule | | | |
| | Execute Self-Schedule | | | |
Propose selected activities for CAST
Approved at Weekly Plan Review

Hide CAST activities from OPTIMIS
Create & add supporting CAST planning data

Crew makes plan in Playbook
CAST team manages process for the approve crew’s plan
Approved crew plan incorporated into OPTIMIS

Cleanup activity’s stowage & execution notes
Duplicate OPTIMIS plan in Playbook
Day of Execution

- **3 weeks before**
  - E-3 O3

- **7 days before**
  - E-2 O1
  - E-2 O2

- **5 days before**
  - E-2 O3

- **2 days before**
  - E-1 O1

CAST activities not visible in OPTIMIS (ISS Viewer Software)

CAST plan visible in OPTIMIS

Planning Product Change Requests submitted, approved, and implemented in OPTIMIS

Crew plans in Playbook

Cleanup & duplicate plan in Playbook

Crew plans in Playbook
SELF-SCHEDULING GUIDANCE

One astronaut given a number of activities to self-schedule.

Astronaut given guidance as to the priorities of the activities to be scheduled.

Astronaut would use Playbook to self-schedule.
PLAYBOOK

Playbook is an easy-to-use mobile web-based plan-execution tool that is designed for crew.

Features include collaborative self-scheduling with constraint checking and violation visualizations, full activity execution status capabilities, condition band support, task list support, IPV XML procedure linking support.

FULLY WORKS WITH CURRENT ISS PLANS.

PLAYBOOK USED FOR 4 YEARS EVALUATING CREW AUTONOMY IN EARTH-ANALOGS.
SELF-SCHEDULING IN PLAYBOOK

---

### Playbook for ISS

<table>
<thead>
<tr>
<th>GMT</th>
<th>06:00</th>
<th>07:00</th>
<th>08:00</th>
<th>09:00</th>
<th>10:00</th>
<th>11:00</th>
<th>12:00</th>
<th>13:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>US/Central</td>
<td>01:00</td>
<td>02:00</td>
<td>03:00</td>
<td>04:00</td>
<td>05:00</td>
<td>06:00</td>
<td>07:00</td>
<td>08:00</td>
</tr>
<tr>
<td>ALL KU AVAIL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALL S AVAIL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DAY/NIGHT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily Orbit</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>ALL VHF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TLM FORM/ATTITUDE</td>
<td>113</td>
<td>123</td>
<td>119</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALL S1 AVAIL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### FE-3

**EXERCISE-ARED**
- 10:55 to 12:25 (90 minutes)
- 2.1.175 - ARED - EXERCISE
- 5.0.100 - ARED - EXERCISE SPREADSHEET REFERENCE

Countermeasures System (CMS) Advanced Resistive Exercise Device (ARED) Exercise Session

**MIDDAY-MEAL**
- 12:25 to 13:25 (60 minutes)
- Midday Meal

**OBT-ISS CMO-CBT**
- 13:25 to 13:50 (25 minutes)
TWO-SERVER SYNCHRONIZATION
ISS ADAPTATION

Playbook is designed to be fully used during LOS.

Once in AOS again, all Playbook data is automatically synchronized between the servers.

This functionality can also be used to automatically synchronize to a backup or mirrored server.

During AOS, all playbook data is synced in near real time (interval set by OPS PLAN/OCA).

Data exchanged using flat files vs. a socket connection.

During LOS, crew can fully use Playbook without a connection to ground.

Once in AOS again, the connection is reestablished and all Playbook data is automatically synchronized between the servers.

Data exchanged using flat files vs. a socket connection.
SELF-SCHEDULING ONBOARD ISS


First time an ISS astronaut scheduled their own tasks, which they executed as planned.

First time an ISS astronaut managed their own schedule to reflect as-run timeline.


(Not part of this presentation)
ConOp for crew self-scheduling is viable in a spaceflight operation environment.

Crew easily planned day & rescheduled as-run day.

Essential to have a software tool that is easy to use for crew but can still support the complexities associated with mission constraints.

Trade between software vs. mission complexity.

High number of constraints associated with individual ISS activities introduced several challenges.

Self-scheduling task difficulty driven by the number of constraints.

Limited the number of activities that could be selected for self-scheduling. Had to select ones that were not overly constrained.
Self-scheduling and review cycle was highly time constrained.

Ops Planners had to synchronize crew self-scheduled activities with OPTIMIS, creating a large number of PPCRs (Planning Product Change Requests).

Once schedule was visible in OPTIMIS, ground teams only had one day to verify self-scheduled activities.

ISS OSO staffing schedule was out-of-sync with finalizing timeline for crew.

Software limitations with seamless integration of activity’s Stowage information.

Playbook issues were difficult to diagnose because it was unclear if issue with software or the synchronization between ground and crew server on ISS.

Lacked ISS-equivalent test platform.
FUTURE WORK

Capture and publish CAST results.

- Compare results from self-scheduling in spaceflight with experiences in Earth-analogs.

Evaluating CAST # 2 to investigate other areas of research:

- More than one crewmember
- Simplifying planning problem for crew
- Minimizing crew time spent scheduling
ACKNOWLEDGEMENTS

Special thank you to the large CAST team that made this all possible: Ivy Deliz, Bob Kanefsky, Jimin Zheng, Crystal Larsen, Neil Woodbury, Shelby Bates, Mikayla Kockler, Brooke Rhodes, William Moore III, Ashley Henninger, Isabelle Edhlund, Mary Kate Smith, William Kockler, and Jackelynne Silva-Martinez.

Support from Lauren Rush Bakalyar, David Korth, Alonso Vera, and Laura Bollweg.

Icons made by Freepik from www.flaticon.com
E-3 Weeks ‘Preview Week’
Execution proposed
Proposal discussed at IEPT
Proposal approved at WPR

E-7 ‘Prelim STP’
No Changes

E-6 ‘Final STP’
Deadline to avoid ‘Cleanup’

E-6 ‘Plan H/O’
CAST team adds extra planning data
CAST team hides CAST crew member’s plan

CAST astronaut plan not visible

CAST crew member’s plan not visible in OPTIMIS
Final STP version available for reference

CAST crew member’s plan in OPTIMIS
CAST team writes PPCR
CAST PPCR processed
CAST PPCR negotiations occur
Cleanup (stow/exec notes)
Other PPCRs to support CAST PPCR

Crew makes plan

Final Orbit 3 approval of E-1
Final Orbit 3
Final Uplink
Duplicat e Final OPTIMIS Plan in Playbook

E-3 Review
mDPC E-2 eDPC E-2

Middle of Orbit 3 on E-2
First hour of Orbit 2 on E-1
Orbit 2 review of E-1
Final Uplink