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

J. J. MARQUEZ[1], S. HILLENIUS[1], & M. HEALY[2]

[1]NASA AMES & [2]SGT, INC. (NASA JOHNSON)

JESSICA.J.MARQUEZ@NASA.GOV

# TODAY'S TALK

Why enable crew self-scheduling?

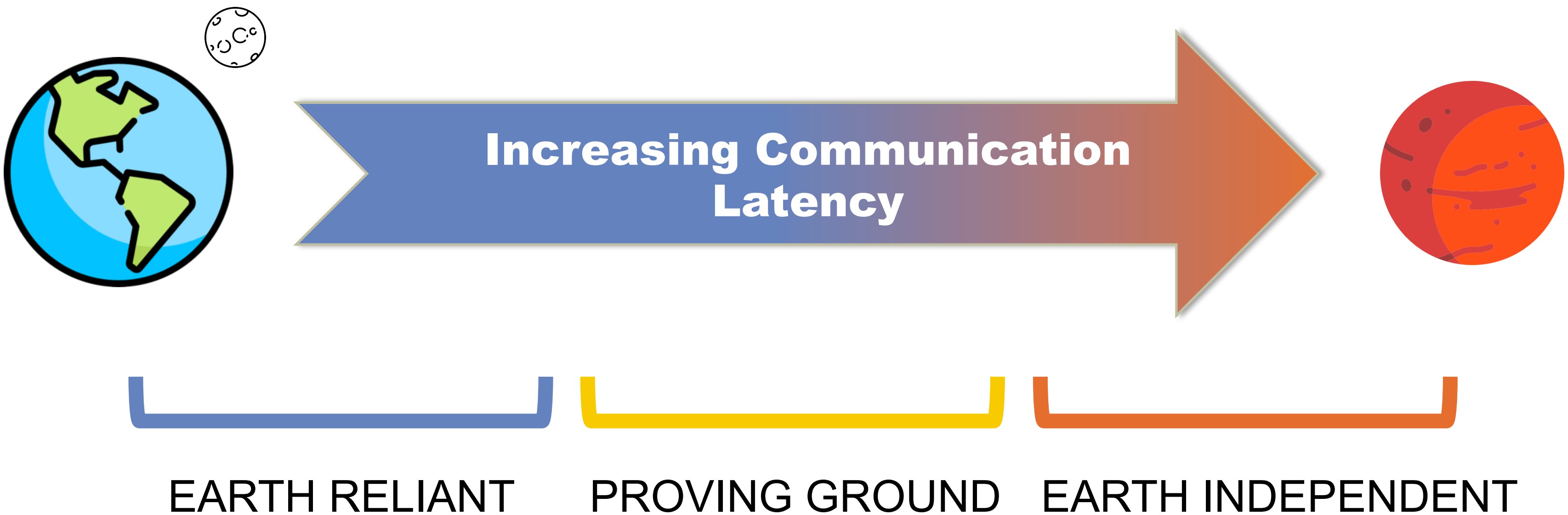
Crew autonomy in the context of ISS environment

Self-Scheduling Software: Playbook

CAST testing onboard ISS

Technical & operational lessons learned

# TOWARDS EARTH-INDEPENDENCE




**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.

# CREW AUTONOMOUS SCHEDULING TEST (CAST)

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

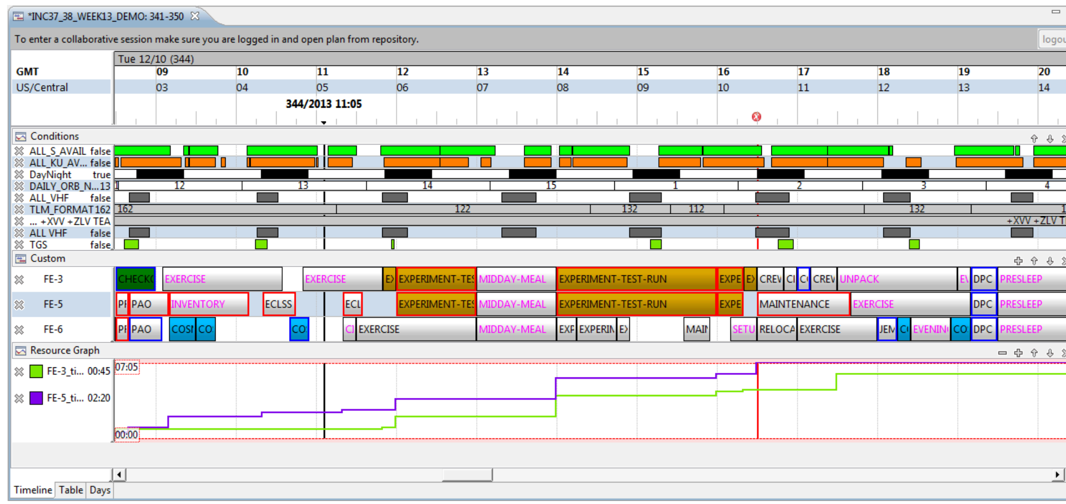
Numerous constraints and resource limitations

Cooperating with various international partners

# ISS OPERATIONAL ENVIRONMENT

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

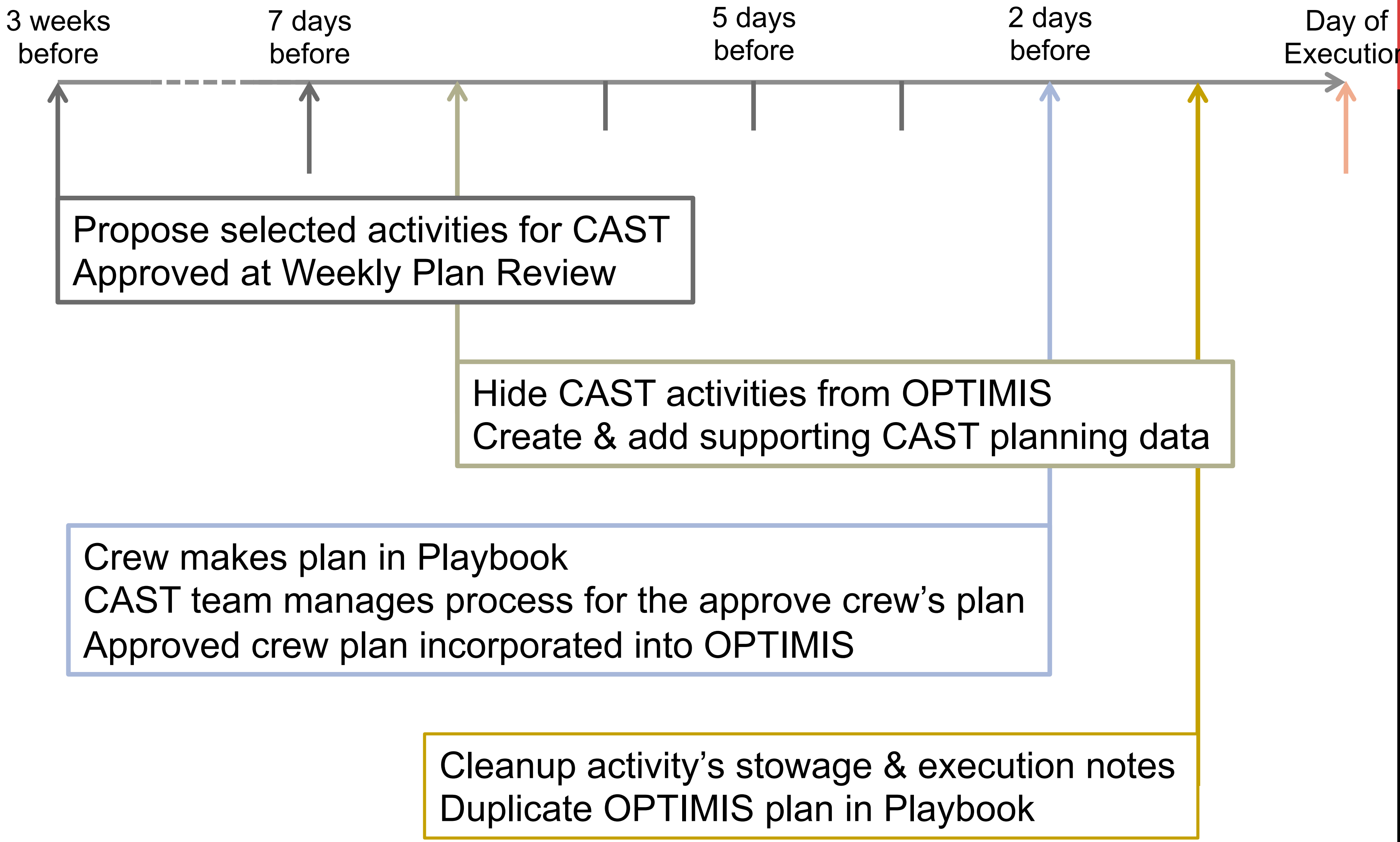
Collect data and debrief from astronaut

# COORDINATING CAST EXERCISES

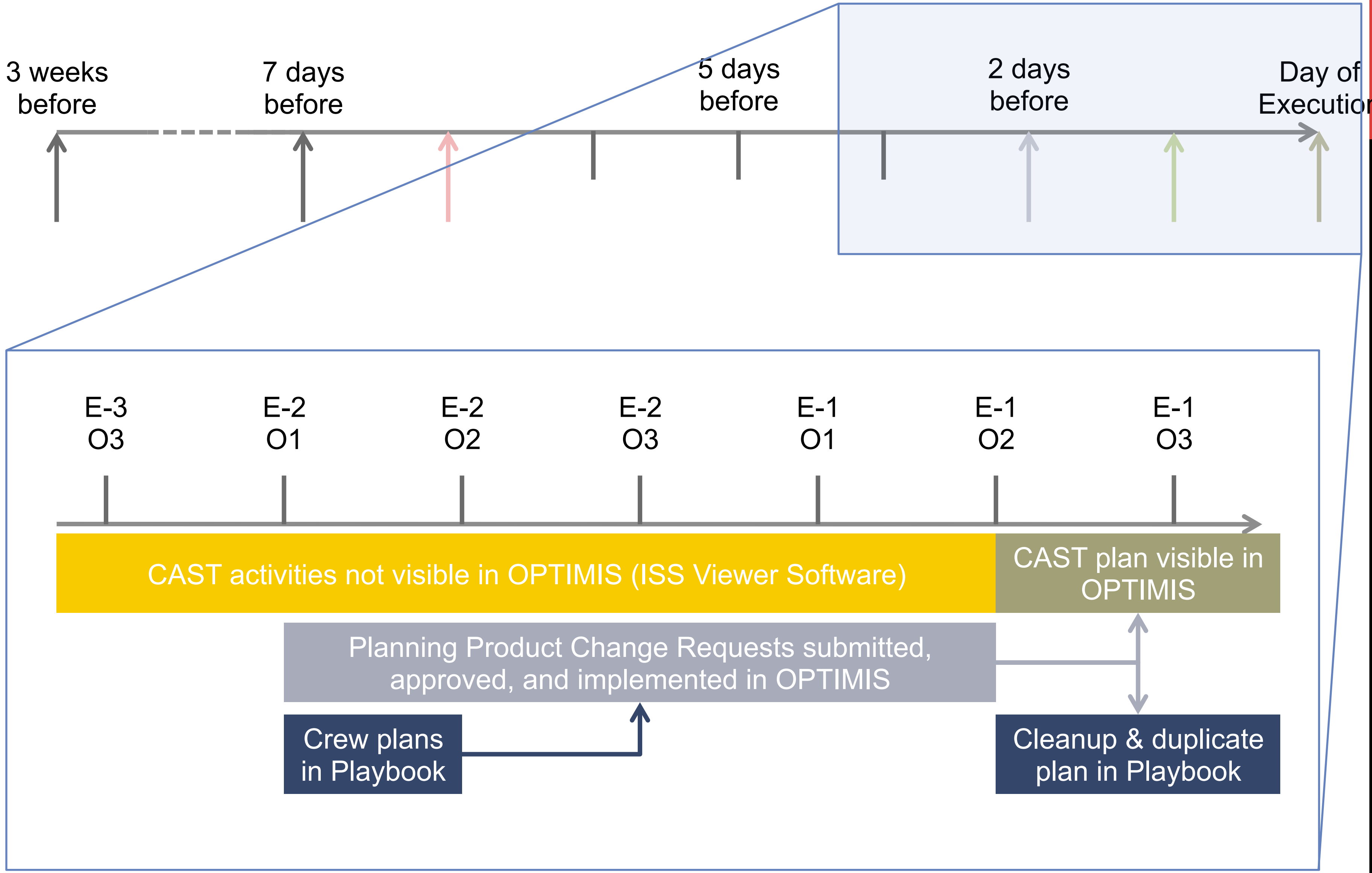
- **Five exercises, increasing the crew's autonomy**
- **Exercises occur on full, nominal, crew days**
  - **Exercise days carefully chosen to capture future mission realism, minimize current mission risks, and maximize investigation return.**

| Familiarization & Training | | Practice | Self-Schedule | | | |
|---|---|---|---|---|---|---|
| Exercise #1 | Exercise #2 | Exercise #3 | Exercise #4 | +2 days | Exercise #5 | +2 days |
| Planning Familiarization (Fake day) | Execution Familiarization (Prepared Plan) | Schedule Afternoon (Limited Planning) | Self-Schedule | Execute Self-Schedule | Self-Schedule | Execute Self-Schedule |

**INCREASING CREW AUTONOMY**



3 weeks before
7 days before
5 days before
2 days before
Day of Execution
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


3 weeks before
7 days before
5 days before
2 days before
Day of Execution
E-3 O3
E-2 O1
E-2 O2
E-2 O3
E-1 O1
E-1 O2
E-1 O3
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

# 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

**52-0169: CAST Session #5 Priority List**

[1] "Total Selected Crew Time" includes your pre-scheduled activities. Note that SPRINT-GUIDE-DON-OPR activity is hard-scheduled with FE-2 SPRINT.

[2] RUN1 and RUN2 of ADC activities are a continuation from earlier in the week and run into next week.

[3] No activities that cause vibration should be scheduled in the LAB during both ADC-MICROSCOPE-OPS activities (i.e. ADC MICROSCOPE-OPS cannot occur during CEVIS).

[4] Scott Tingle will be working with you from the ground on your IMS-STOWAGE-CONF activity.

[5] P/TV ADD CAM VIEW TD must be completed before the P/TV CAM PWR STOW on Friday GMT 202.

**Total Selected Crew Time: 0:15**

| Priority | Activity Name | Duration |
|---|---|---|
| Highest Priority | *Exercise* | (00:00) |
| | EXERCISE-CEVIS | 01:00 |
| | EXERCISE-ARED | 01:30 |
| | *Antibody Conjugates Inoculation Run 1* [2] | (00:00) |
| | ADC-GLACIER-RMV-RUN1 | 00:05 |
| | ADC-MEDIA-INJECTION-RUN1 | 01:15 |
| | ADC-MICROSCOPE-OPS-RUN1 [3] | 01:00 |
| | *Antibody Conjugates Inoculation Run 2* [2] | (00:00) |
| | ADC-GLACIER-RMV-RUN2 | 00:05 |
| | ADC-MEDIA-INJECTION-RUN2 | 01:15 |
| | ADC-MICROSCOPE-OPS-RUN2 [3] | 01:00 |
| | IMS-STOWAGE-CONF [4] | 00:15 |
| | P/TV ADD CAM VIEW TD [5] | 00:05 |
| | CMS-ARED-CAR-FLIP | 01:10 |
| | MELFI-DEWAR-INV | 00:10 |
| | WANTED-BUMP-SHIELD | 00:30 |
| | J-RSU SENSOR-CORRECT | 00:40 |
| | MD-LAUGH-PRINT-VID | 00:15 |
| | CHeCS RACK-AUDIT-PT2 | 01:00 |
| | XFER-RS-ITEMS | 00:20 |
| | BEAM-IMV-INSPCT&CLN | 00:50 |
| | CHRCL FIL-BAG-VERIFY | 00:20 |

# PLAYBOOK

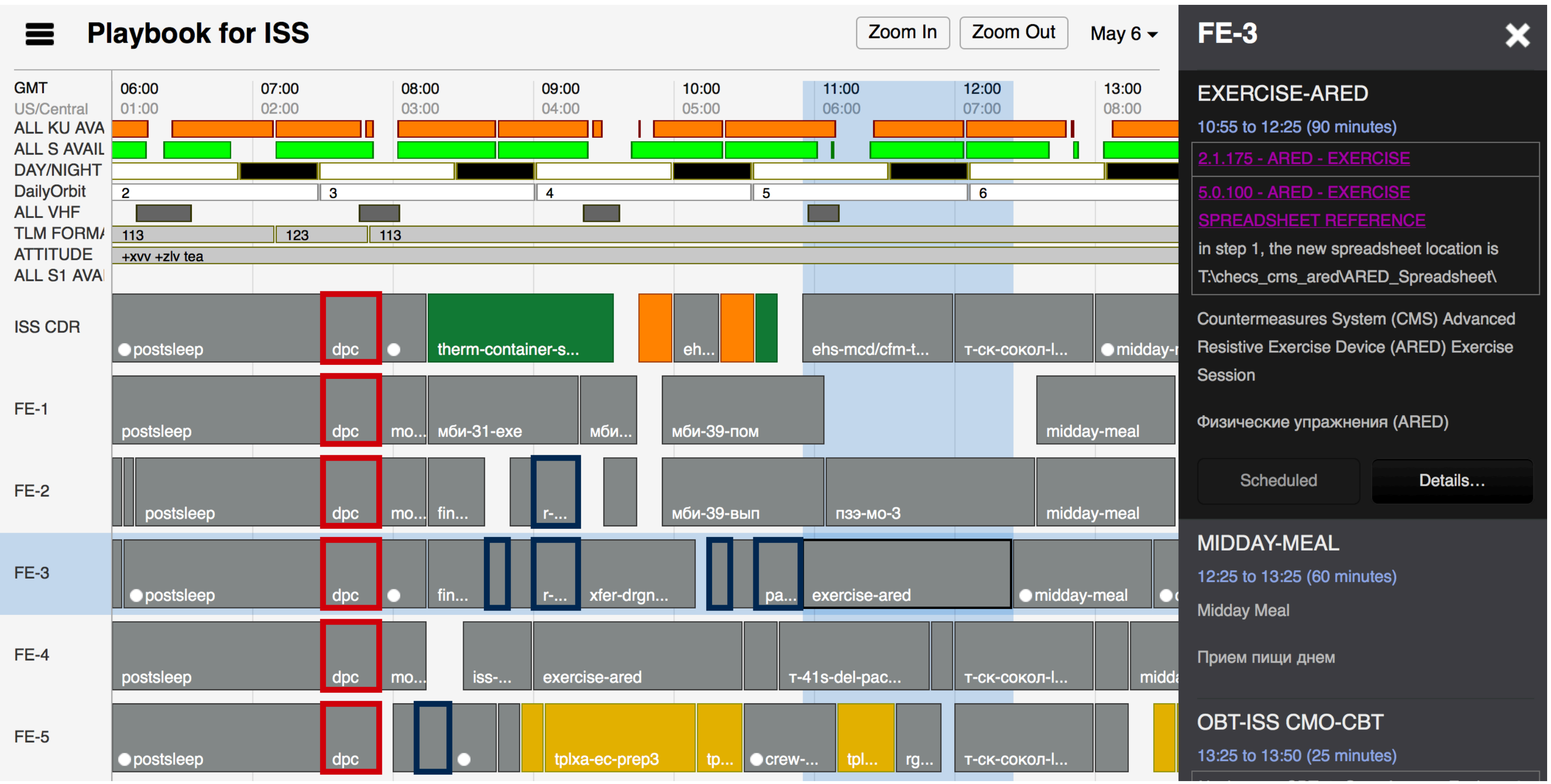
**Playbook is an easy-to-use mobile web-based plan-execution tool that is designed for crew.**

**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

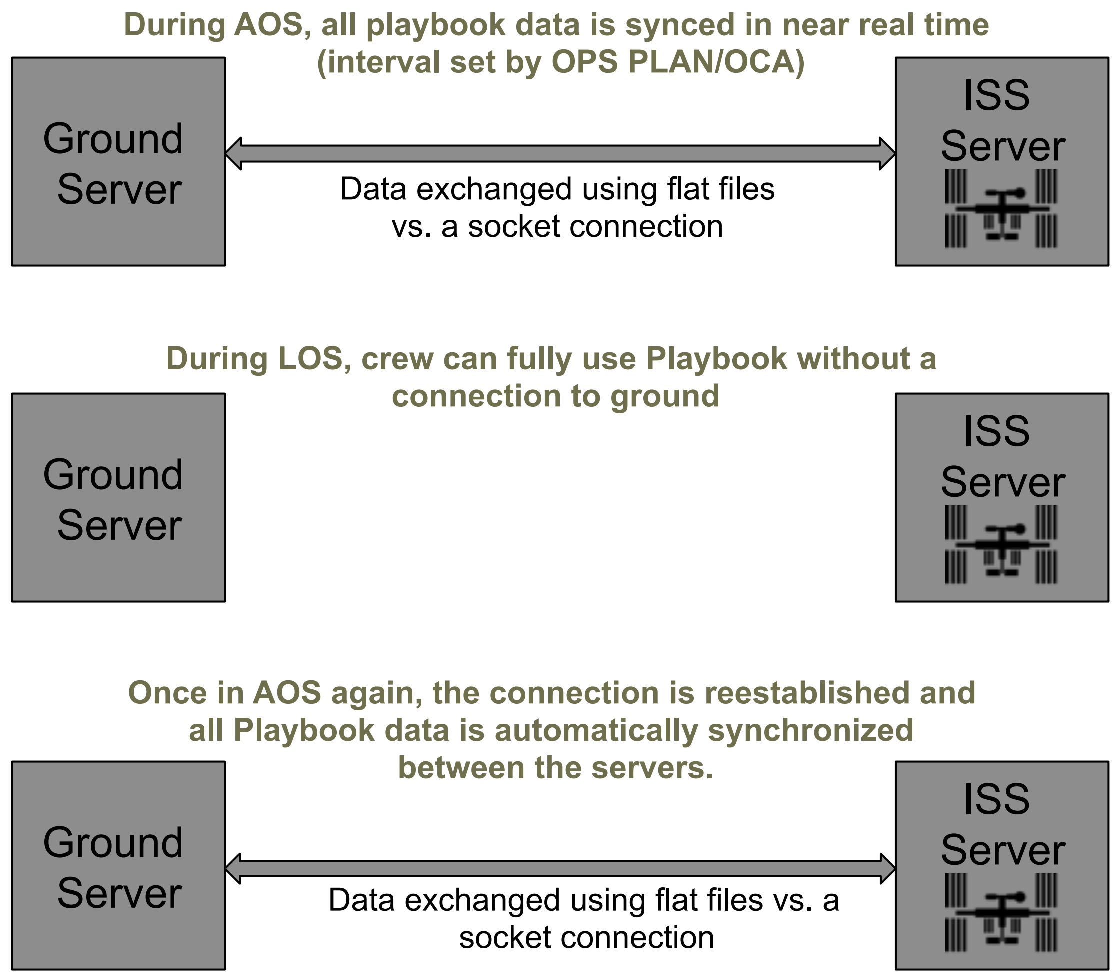


# TWO-SERVER SYNCHRONIZATION ISS ADAPTATION

**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.**



# SELF-SCHEDULING ONBOARD ISS

Five CAST exercises completed between 12/2016 – 7/2017.

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.

Surveys filled out after Exercises 4 and 5. Debrief held at NASA JSC 9/2017.

*(Not part of this presentation)*

# TECHNICAL & OPERATIONAL LESSONS LEARNED

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.

# TECHNICAL & OPERATIONAL LESSONS LEARNED, CONT.

- 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

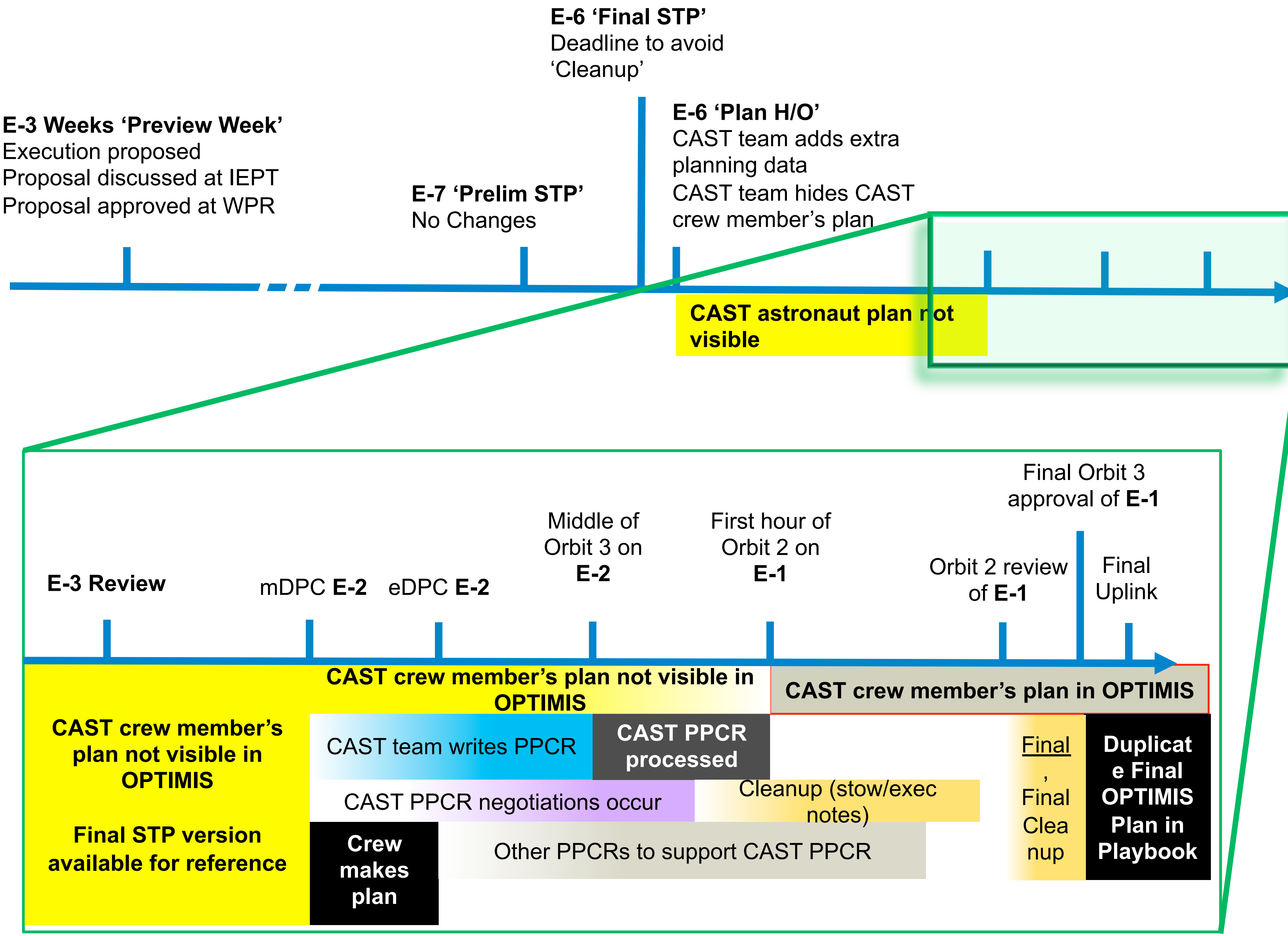
**Special thank you to the large CAST team that made this all possible: Ivy Deliz, Bob Kanefsky, Jimin Zheng, Crystal Larsen, Neil Woodbury, Shelby Bates, Mikayla Kockler, Brooke Rhodes, William Moore III, Ashley Henninger, Isabelle Edhlund, Mary Kate Smith, William Kockler, and Jackelynne Silva-Martinez.**

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




**Icons made by Freepik from www.flaticon.com**

# BACKUP SLIDES



E-6 'Final STP'
Deadline to avoid 'Cleanup'
E-3 Weeks 'Preview Week'
Execution proposed
Proposal discussed at IEPT
Proposal approved at WPR
E-7 'Prelim STP'
No Changes
E-6 'Plan H/O'
CAST team adds extra planning data
CAST team hides CAST crew member's plan
CAST astronaut plan not visible
Final Orbit 3 approval of E-1
Middle of Orbit 3 on E-2
First hour of Orbit 2 on E-1
E-3 Review
mDPC E-2
eDPC E-2
Orbit 2 review of E-1
Final Uplink
CAST crew member's plan not visible in OPTIMIS
CAST crew member's plan in OPTIMIS
CAST crew member's plan not visible in OPTIMIS
Final STP version available for reference
CAST team writes PPCR
CAST PPCR processed
CAST PPCR negotiations occur
Cleanup (stow/exec notes)
Crew makes plan
Other PPCRs to support CAST PPCR
Final, Final Cleanup
Duplicate Final OPTIMIS Plan in Playbook