Integrating Mission Timelines and Procedures to Enhance Situational Awareness in Human Spaceflight Operations

John A. Karasinski, Jimin Zheng, Melodie Yashar, Jessica J. Marquez

SpaceCHI 2.0, May 1, 2022

Introduction

Astronauts on the ISS have significant real-time support from mission control centers (MCC) on the ground.

Future missions to Mars have comm challenges:

- Delayed communications
- Limited bandwidth
- Solar conjunction

Result is dangerously reduced situational awareness for both MCC and crews.

Enabling Crew Autonomy

Crew autonomy: the ability for astronauts to execute tasks **more independently** from MCC.

Requires a substantial change in NASA's current concept of operations and must be supported with new technologies.

We propose that one way of improving the state-of-the-art for crew autonomy is to better integrate two of the software systems that currently support task execution: timeline and procedures management.

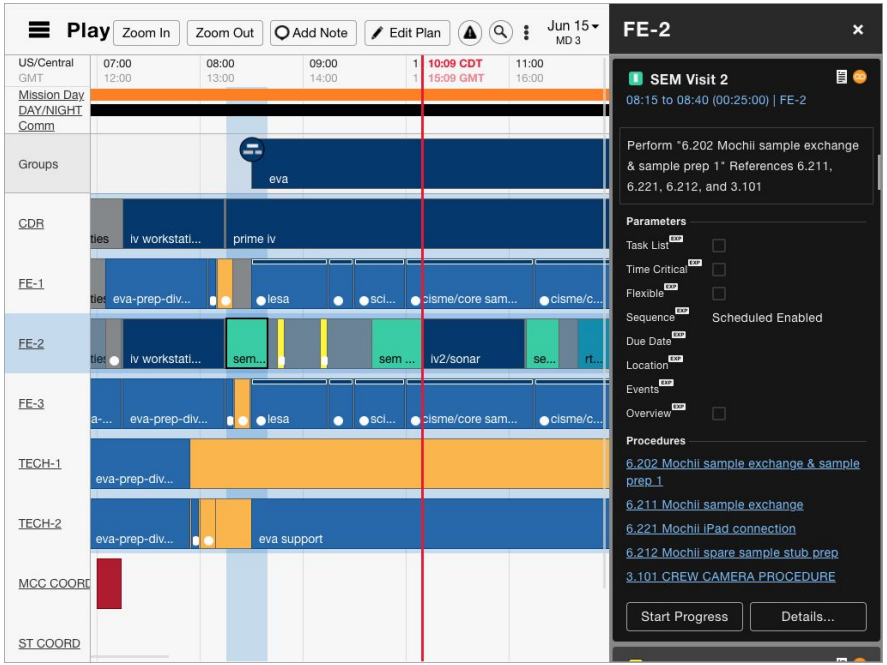
Usability Study

To evaluate some of these ideas for procedure and timeline integration, we conducted a series of usability studies with

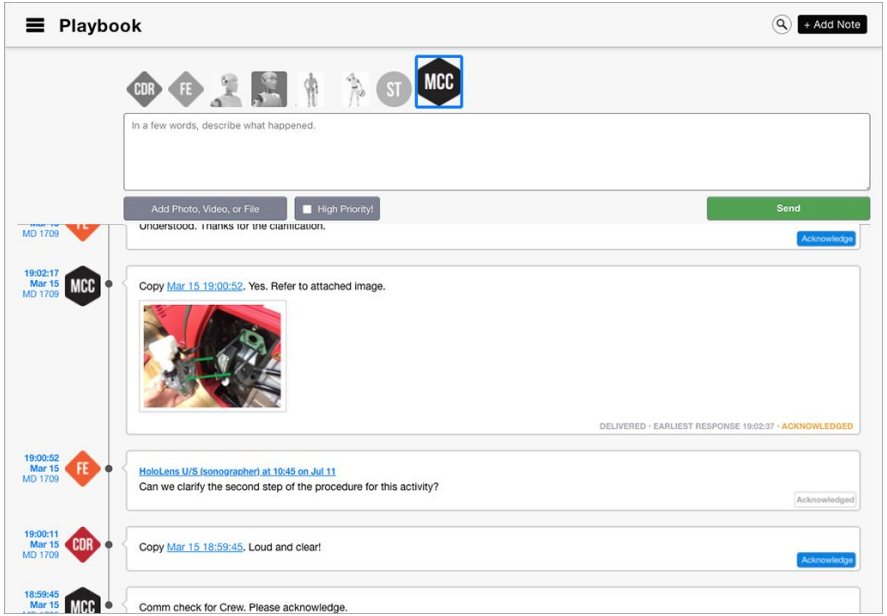
- space operations-naive participants, and
- individuals who have experience with ISS flight operations.

The goal of the usability studies was to **investigate different techniques for improving general situational awareness among flight controllers** during spaceflight missions by providing enhanced electronic procedures and systems data alongside mission timelines.

Playbook



Playbook's Timeline provides detailed activity information across a mission plan

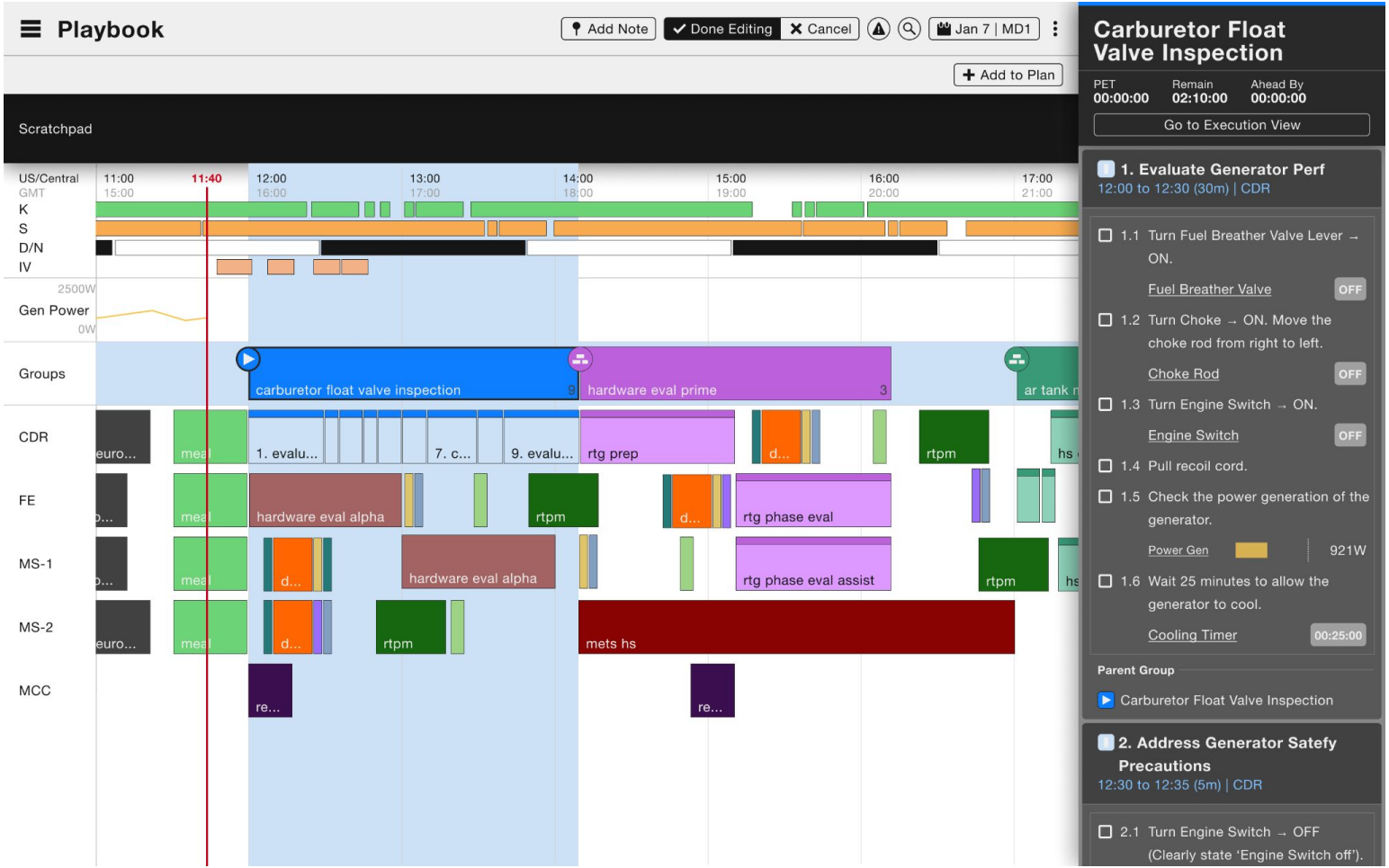


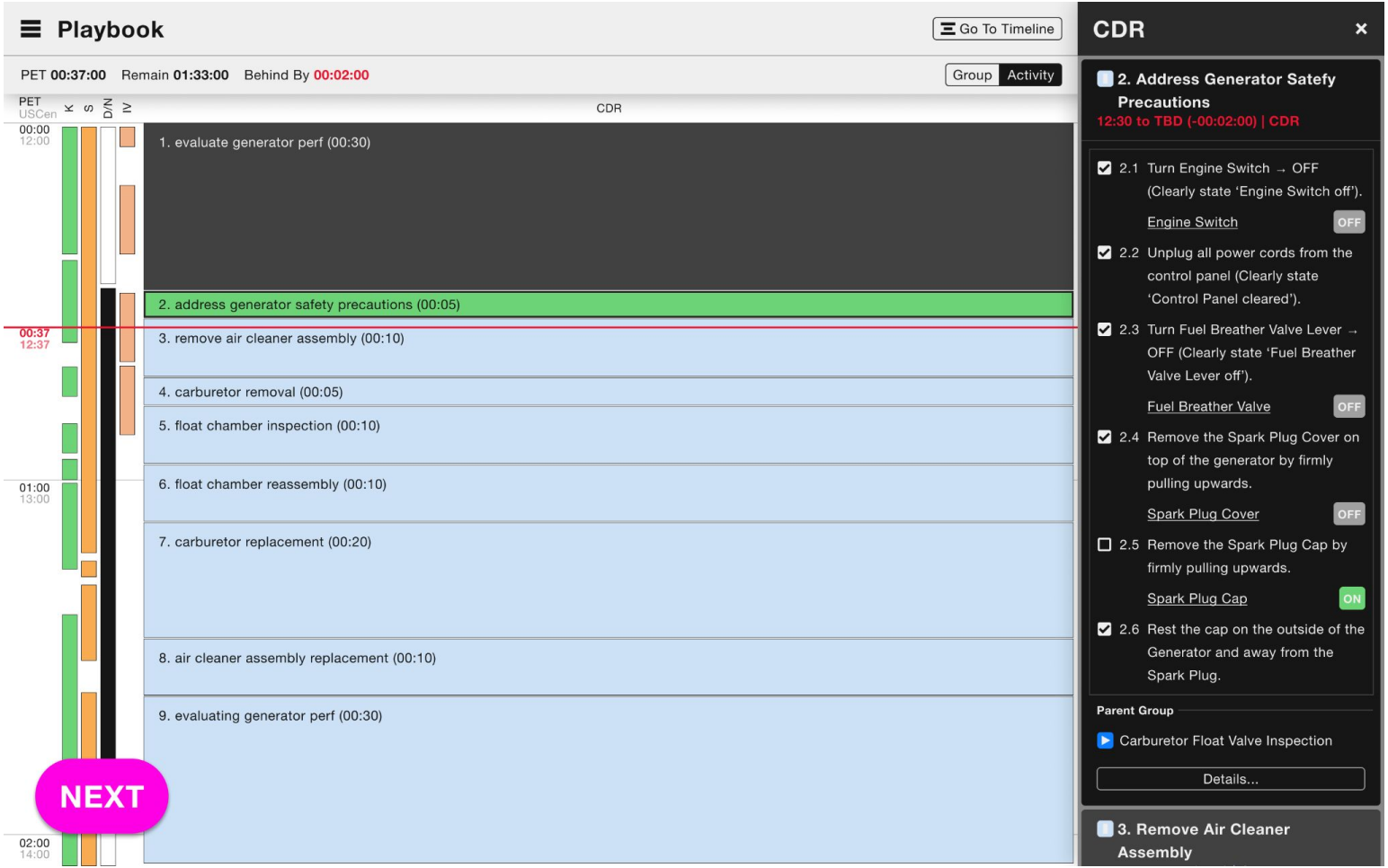
Playbook's Mission Log feature enables text and multimedia communications in simulated communication delay environments

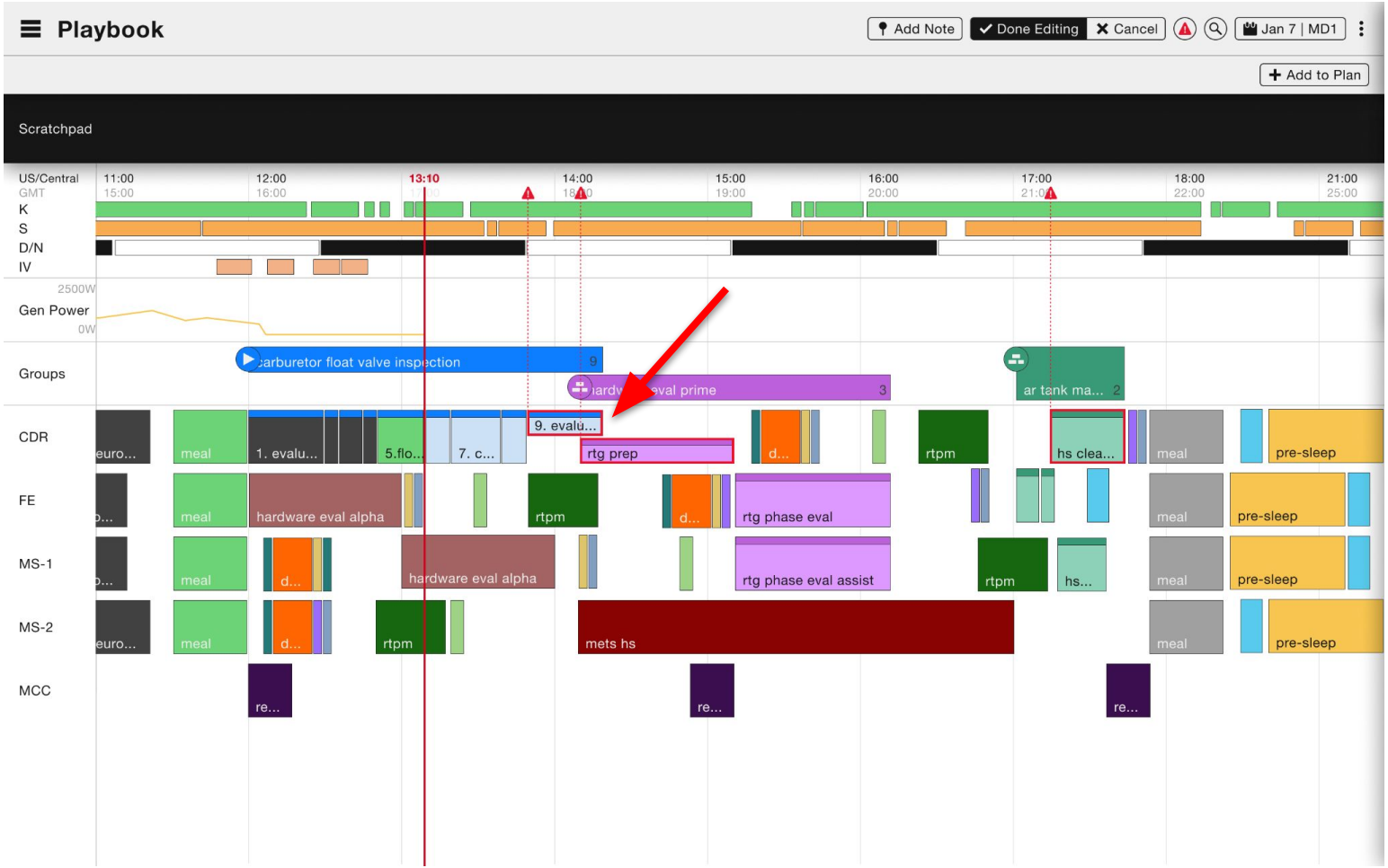
Usability Study

Participant prompt:

> Imagine you are a flight controller in the mission control center for ISS. You are on-console monitoring the overall mission timeline in Playbook as the crew conduct their activities. As an operations planner, **your goal is to make sure that crew members stay on task and on schedule, and have resolutions prepared if there are ever deviations from the planned timeline**. In the following scenario, you will be monitoring the crew member's progress as they start "Carburetor Float Valve Inspection."


Playbook
Add Note
Done Editing
Cancel
Jan 7 | MD1
Add to Plan
Scratchpad
US/Central
GMT
11:00
15:00
11:40
12:00
16:00
13:00
17:00
14:00
18:00
15:00
19:00
16:00
20:00
17:00
21:00
K
S
D/N
IV
2500W
Gen Power
0W
Groups
carburetor float valve inspection
9
hardware eval prime
3
ar tank r
CDR
euro...
meal
1. evalu...
7. c...
9. evalu...
rtg prep
d...
rtpm
hs
FE
hardware eval alpha
rtpm
d...
rtg phase eval
MS-1
meal
d...
hardware eval alpha
rtg phase eval assist
rtpm
MS-2
euro...
meal
d...
rtpm
mets hs
MCC
re...
re...
Carburetor Float Valve Inspection
PET
00:00:00
Remain
02:10:00
Ahead By
00:00:00
Go to Execution View
1. Evaluate Generator Perf
12:00 to 12:30 (30m) | CDR
1.1 Turn Fuel Breather Valve Lever → ON.
Fuel Breather Valve
OFF
1.2 Turn Choke → ON. Move the choke rod from right to left.
Choke Rod
OFF
1.3 Turn Engine Switch → ON.
Engine Switch
OFF
1.4 Pull recoil cord.
1.5 Check the power generation of the generator.
Power Gen
921W
1.6 Wait 25 minutes to allow the generator to cool.
Cooling Timer
00:25:00
Parent Group
Carburetor Float Valve Inspection
2. Address Generator Satefy Precautions
12:30 to 12:35 (5m) | CDR
2.1 Turn Engine Switch → OFF (Clearly state 'Engine Switch off').


Playbook
Go To Timeline
PET 00:37:00
Remain 01:33:00
Behind By 00:02:00
Group
Activity
PET
USCen
K
S
D/N
V
CDR
00:00
12:00
1. evaluate generator perf (00:30)
2. address generator safety precautions (00:05)
00:37
12:37
3. remove air cleaner assembly (00:10)
4. carburetor removal (00:05)
5. float chamber inspection (00:10)
01:00
13:00
6. float chamber reassembly (00:10)
7. carburetor replacement (00:20)
8. air cleaner assembly replacement (00:10)
9. evaluating generator perf (00:30)
NEXT
02:00
14:00
CDR
2. Address Generator Safety Precautions
12:30 to TBD (-00:02:00) | CDR
2.1 Turn Engine Switch → OFF (Clearly state 'Engine Switch off').
Engine Switch
OFF
2.2 Unplug all power cords from the control panel (Clearly state 'Control Panel cleared').
2.3 Turn Fuel Breather Valve Lever → OFF (Clearly state 'Fuel Breather Valve Lever off').
Fuel Breather Valve
OFF
2.4 Remove the Spark Plug Cover on top of the generator by firmly pulling upwards.
Spark Plug Cover
OFF
2.5 Remove the Spark Plug Cap by firmly pulling upwards.
Spark Plug Cap
ON
2.6 Rest the cap on the outside of the Generator and away from the Spark Plug.
Parent Group
Carburetor Float Valve Inspection
Details...
3. Remove Air Cleaner Assembly


Playbook
Add Note
Done Editing
Cancel
Jan 7 | MD1
Add to Plan
Scratchpad
US/Central
GMT
11:00
15:00
12:00
16:00
13:10
14:00
15:00
19:00
16:00
20:00
17:00
21:00
18:00
22:00
21:00
25:00
K
S
D/N
IV
2500W
Gen Power
0W
Groups
carburetor float valve inspection 9
eval prime 3
ar tank ma... 2
CDR
euro...
meal
1. evalu...
5.flo...
7. c...
9. evalu...
rtg prep
d...
rtpm
hs clea...
meal
pre-sleep
FE
meal
hardware eval alpha
rtpm
d...
rtg phase eval
meal
pre-sleep
MS-1
meal
d...
hardware eval alpha
rtg phase eval assist
rtpm
hs...
meal
pre-sleep
MS-2
euro...
meal
d...
rtpm
mets hs
meal
pre-sleep
MCC
re...
re...
re...

Usability Results

We used Nielsen's severity ratings to reveal the most serious usability problems.

From the usability studies, the following major or higher usability takeaways emerged:

- Verbiage and nomenclature
- Visual scale and salience of information
- Meaning of color
- Expected state vs current state

All participants noted that the additional information provided by the graph and the progress and status indicators was helpful to provide insight into task execution progress, but participants interpreted the new features in inconsistent ways.

Closing Thoughts

The development of future crew systems and human systems integration architectures must focus on enabling crew autonomy in the absence of real-time mission support.

These systems will provide enhanced situational awareness to both a remote MCC and to crew within the spacecraft.

By providing tighter integration between timelines and procedures, future interfaces can support crew by suggesting dynamic, constraint-free plans that allow for successful missions in the presence of anomalies.

Thank you!

john.karasinski@nasa.gov