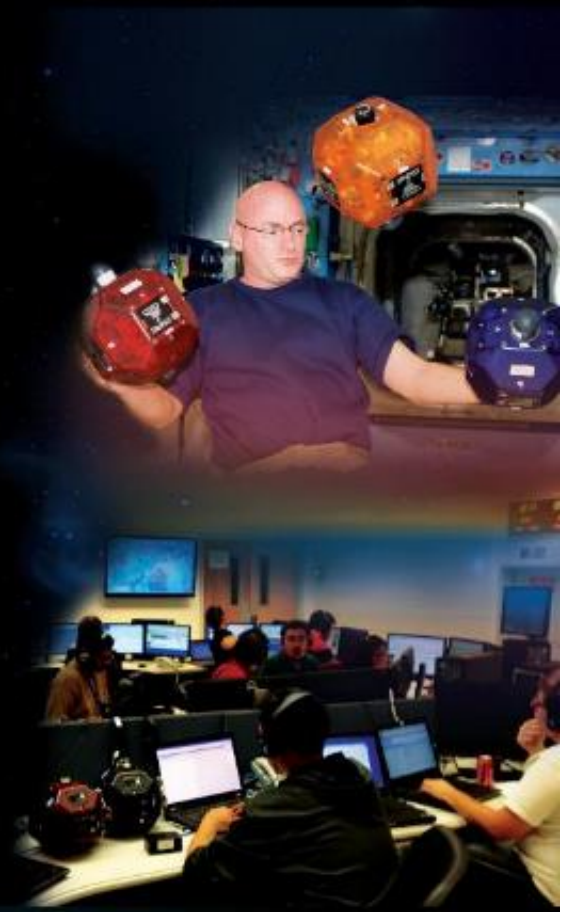
SPHERES

Synchronized, Position, Hold, Engage, Reorient, Experimental Satellites



SPHERES/Astrobee Working Group (SAWG)
Quarterly Meeting

Feb 28th, 2018

Agenda

SPHERES/Astrobee Working Group		Join by phone 1-844-467-4685; 226968			
Date:	Feb. 27th, 2018, 11pm PST	Virtual			
Agenda	Group	Project	Name	Time	duration (min)
A	NASA Ames	SPHERES/Astrobee Facility	Jose Benavides	11:00 PM	0:15
B	JAXA	Int-Ball	Wada Masaru	11:15 PM	0:15
C	AIRBUS/DLR	CIMON	Christian Karrasch	11:30 PM	0:15
	Followon Discussion			11:45 PM	0:15
Date:	Feb. 28th, 2018, 9am PST	Virtual			
Agenda	Group	Project	Name	Time	duration (min)
1	NASA Ames	SPHERES/Astrobee Facility	Jose Benavides	9:00 AM	0:20
2	Stanford	Gecko-Inspired Adhesive Appendages for Automa	Marco Pavone	9:20 AM	0:10
3	MIT	SPHERES SmoothNav, ReSWARM, Zero Robotics	Alvar/Danilo/Katie	9:30 AM	0:10
4	FIT	RINGS/SVGS	Hector	9:40 AM	0:10
5	NASA Logistics	REALM-2	Andres Chu	9:50 AM	0:10
6	University of Lisbon, Portugal		Rodrigo Ventura	10:00 AM	0:10
7	Airbus	Tether-Slosh	Hans	10:10 AM	0:10
8	Naval Postgraduate School	Propellantless mobility for spacecraft	Marcello Romano	10:20 AM	0:10

SPHERES Community

❑SPHERES Working Group (SWG) Quarterly meeting

- Membership includes MIT, FIT, AFS, DARPA, CASIS, Airbus, and NASA (HQ, KSC, JSC, MSFC, and ARC)
- Face-to-Face, twice a year
- Next will be scheduled in May 2018, location TBD

❑ Purpose:

- Information sharing across the SPHERES/Astrobee community
- Astrobee Facility shares
  - ✓ National Lab Facility availability
  - ✓ Status of resources (batteries, CO2 tanks, etc.),
  - ✓ Overall Calendar (scheduled Test Sessions, upmass/return), and
  - ✓ Updates on “new” PD, Investigations, and ISS infrastructure.
- Provide the SPHERES/Astrobee community (PD, investigators, etc.) with up-to-date information to determine opportunities to use the NL Facility
- Discuss proposed changes/updates to Astrobee Nat Lab which may be required to support a specific activity or research.
- Discuss specific support requests made to the ISS Office

Today's Goals

❑ The SPHERES/Astrobee Facility success as a platform for technology development and fundamental research depends on the success of it's users

- What's your current goal with Astrobee? (Lab Demo? ISS Demo?)
- Plan for getting there
- Are there some make-sense partnerships with other groups here?

Goals (Free Flyer Community)

❑ Sharing of information and lessons learned

❑ Explore opportunities in Interoperability

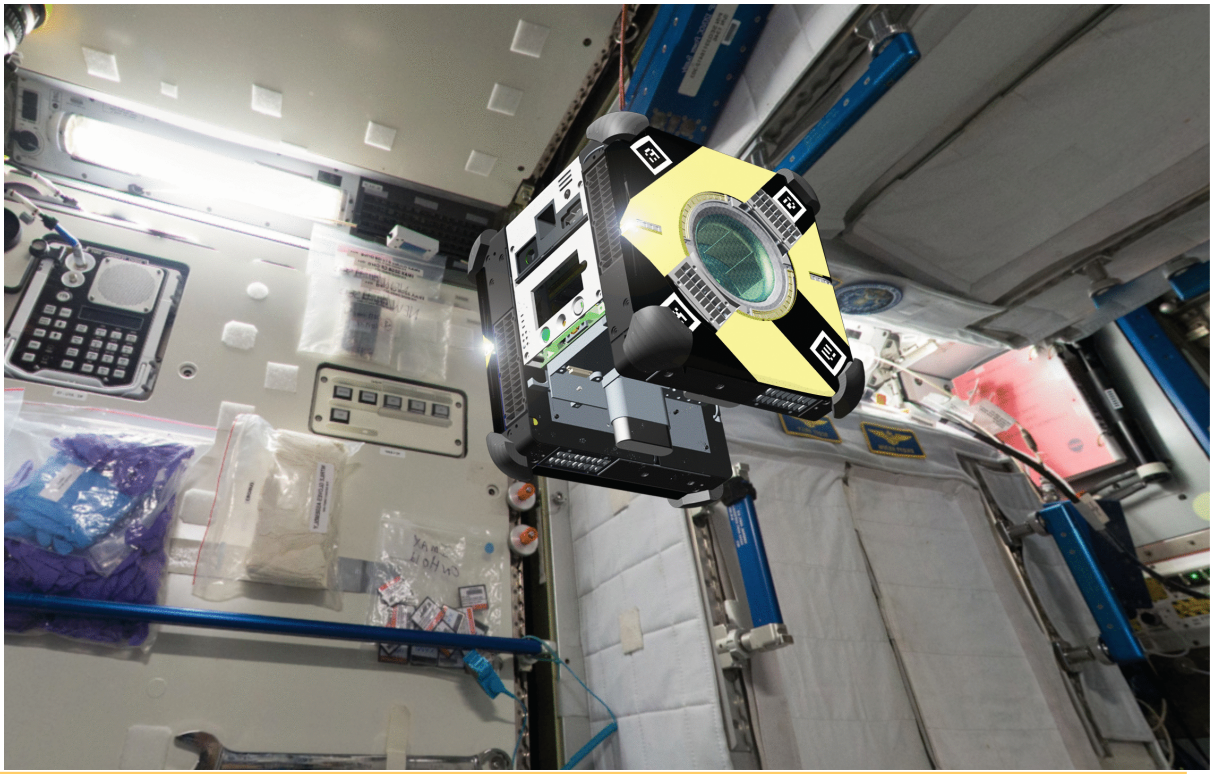
- Reference: “CCSDS Report Concerning Space Data System Standards, Telerobotic Operations”
- https://public.ccsds.org

First exchange/collaboration meeting between Astrobee and Int-Ball teams

- **Multiple meetings held in Japan in January, 2018**
- **Int-Ball – Astrobee meeting**
  - Introduction of Astrobee and Int-Ball designs/systems
  - Possible collaboration among teams
- **JAXA/NASA TIM meeting**
  - Use cases for simultaneous operation of Int-Ball and Astrobee

What's next …

- Next ZR competition is under way
- Continuing Vertigo Smooth Navigation research
- Continuing Tether-Slosh
- New SPHERES-ReSWARM
- **Continue work transitioning to Astrobee**
  - Goal: Fully operational in 2019
- First Astrobee Users
  - REALM-2
  - Zero Robotics
  - Astrobotics/Bosch
- Astrobee Users in the wings
  - Stanford
  - NPS



Guest Science Program (GSP)

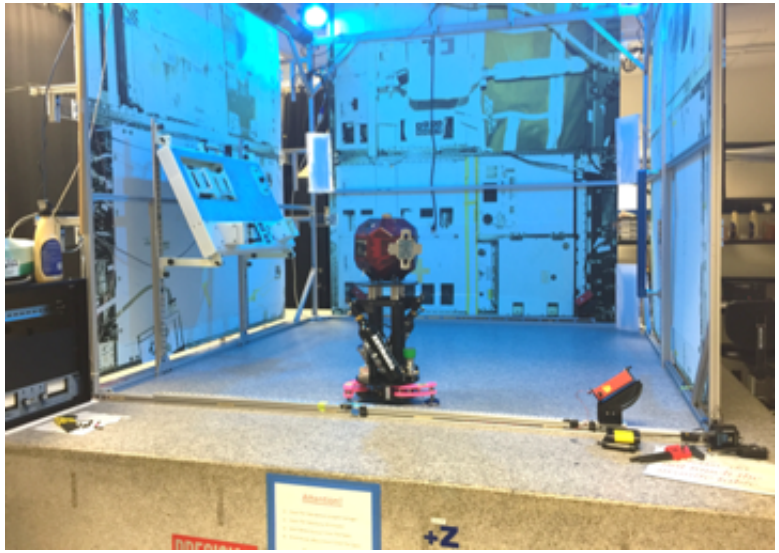
- What's available from the Astrobee Facility?
  - Astrobee Robotics Software Simulation
  - Ground Hardware: Qty 3 & ”Flat-Sats”
  - Labs: Granite & MGTF
  - Documentation and Training
  - Proposal Support
  - ISS Payload Partner
- How can I use Astrobee and what does it take?
  - Guest Scientist Guide & Mechanical Payload ICD
  - New Hardware or ”just” Software?
  - Ground Demonstration or ISS Operation?
- We want to hear from you!
  - Approximate Scheduling
- Information found on website

https://www.nasa.gov/astrobee

SPHERES Engineering

Ground Lab Status

- Granite Lab: Online



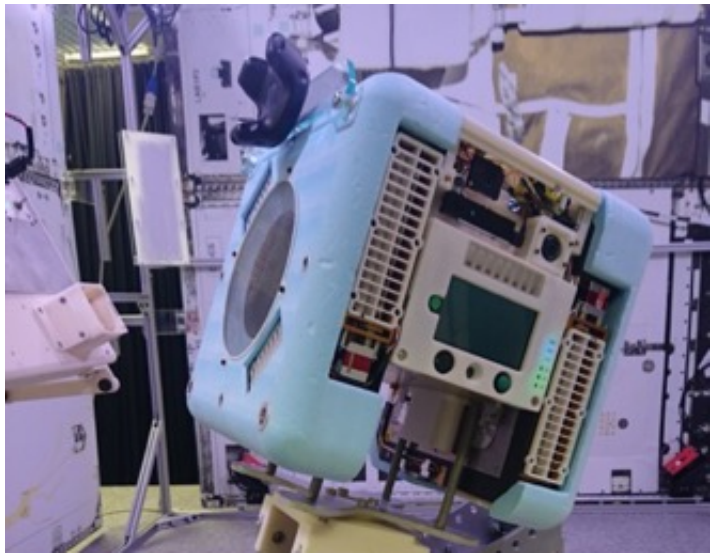
- Flight Lab: Online

- Micro Gravity Test Facility (MGTF) Lab

- Engineering Evaluation Lab (EEL): Available upon request

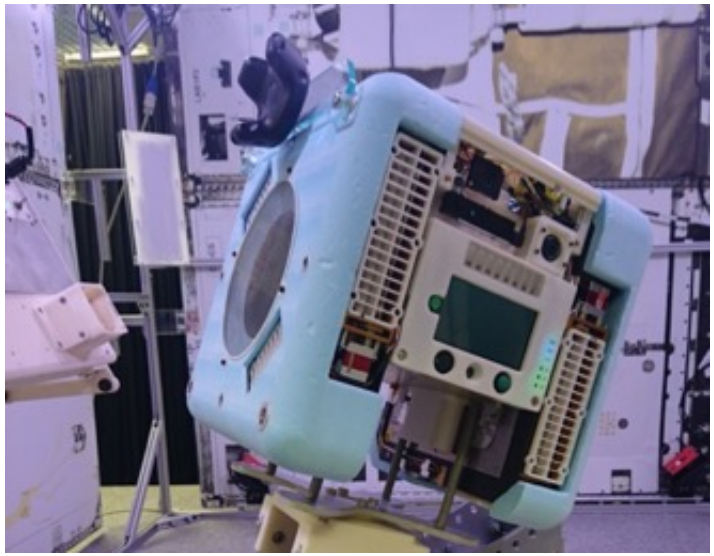
Hardware Fidelity (Astrobee)

Name	Mechanical Fidelity	Electrical Fidelity	Software Fidelity	Sensor Fidelity
P4C	Low	Low	Low	High
P4E	Med	Med-High	High	High
Flat Sat A	Low	High	High	Low/None
Cert	High	High	High	High
Flight 1	High	High	High	High



Hardware Status (Astrobee)

Name	Status	Plans
P4C	End-Of-Life	Available in MGTF but unsupported
P4E	Operational	Dev. Testing in Granite until Cert, then MGTF
Flat Sat A	Operational	JSL testing 03/06, REALM testing during visit
Cert	In-Work	Complete by 04/06, then verification testing
Flight 1	In-Work	Complete by 04/06, then verification testing

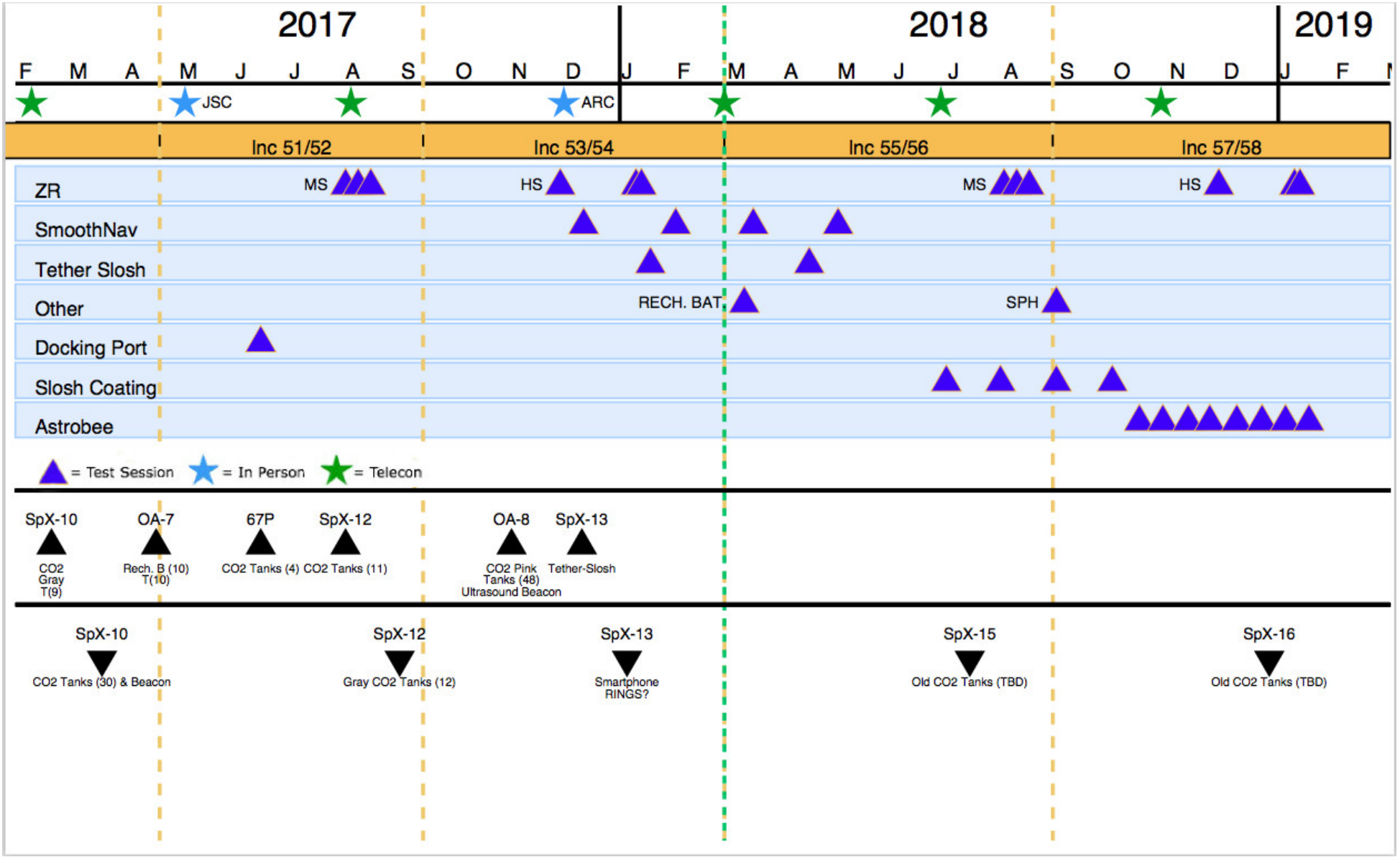


SPHERES & Astrobee Operations

Increments 53/54 (Sept 2017-Feb 2018)

- **Increments 53/54 (Sept 2017-Feb 2018)**
  - SmoothNav Science 1 — December 11, 2017
  - Zero Robotics High School Dry Run — January 9, 2018
  - Zero Robotics High School Finals — January 11, 2018
  - Tether Slosh Science 1 — January 17, 2018
  - SmoothNav Science 1 Repeat — January 30, 2018
- **Increments 55/56 (Feb 2018 – Aug 2018)**
  - SmoothNav Science 2 — March 2018
  - Tether Slosh Science 2 — March-April 2018
  - SmoothNav Science 3 — ~May 2018
  - SmoothNav Science 4 — June-July 2018
  - Zero Robotics High School Dry Run — July 2018
  - Zero Robotics High School Dry Run — August 2018
  - Zero Robotics High School Finals — August 2018
  - Additional, Tether Slosh (?), new ReSwarm, Slosh Coating — All TBD

SPHERES Calendar



Consumables Status

CO2 Tank Inventory

- **76 Tanks on orbit – should support approximately 23 test sessions**

Battery Pack Inventory

- **62 Batteries on orbit - should support approximately 9 test sessions**
- 10 SPHERES Rechargeable Batteries arrived on station with OA-7 – procedures approved for testing.

PIM Update

PIM Status

- **What integration work has been accomplished since last SPHERES Quarterly Working Group on 11/30/2017?**

  - **SPHERES Tether Slosh – Flight SpX-13 (12/8/17)**
    - January 17th – SPHERES Tether Slosh Run #1
    - One test session remains (for Inc. 55/56). Additional test sessions to be requested.

  - **SmoothNav –** Total of 4 test sessions
    - 1st test session completed: 12/11/17
    - Run #1 –rerun completed: 1/31/18
    - 3 test sessions remain

  - **RINGS – launched on Flight HTV-4 (08/03/13)**
    - RINGS (qty. 2) to potentially return on SpX-14
    - 16 DeWalt batteries on the ground will be transitioned over to JSC/Flight Crew Systems (FCS) group. 8 Dewalt batteries remained on-board and will also be transitioned over to FCS group.

PIM Status--continued

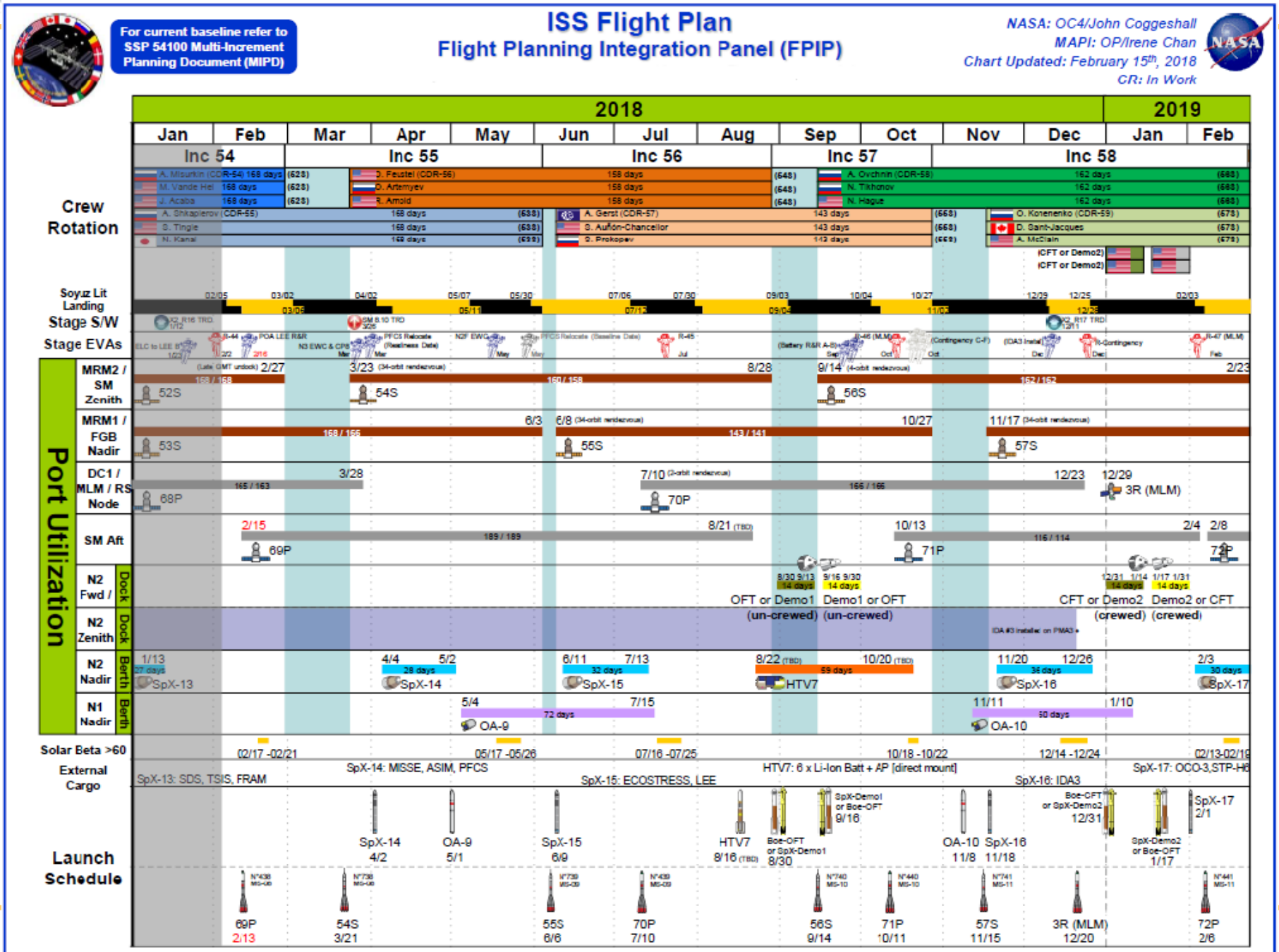
- **SPHERES Zero Robotics:**
  - Inc. 53/54 (09/02/17-02/27/18): completed
    - ZR Unit Test: 11/28/17
    - ZR Dry Run: 01/09/18
    - ZR Competition: 01/11/18

- **Smartphone Hardware- Flight SpX-13 return (1/06/18)**
  - HET Smartphone (launched on ULF7) and Smartphone-MM (launched on Orb-2) returned on SpX-13; will be delivered to Ames by end of March 2018

- **SPHERES ReSwarm – on-orbit investigation only**
  - CASIS approved – not yet added to IPL

- **SPHERES Consumables - multiple flights**
  - Rechargeable batteries –procedures and planning products in work to use these on-orbit.

ISS Flight Plan (in-work version as of 02/27/18)



Astrobee Update

SPHERES/Astrobee Working Group

February 28, 2018

Astrobee Team

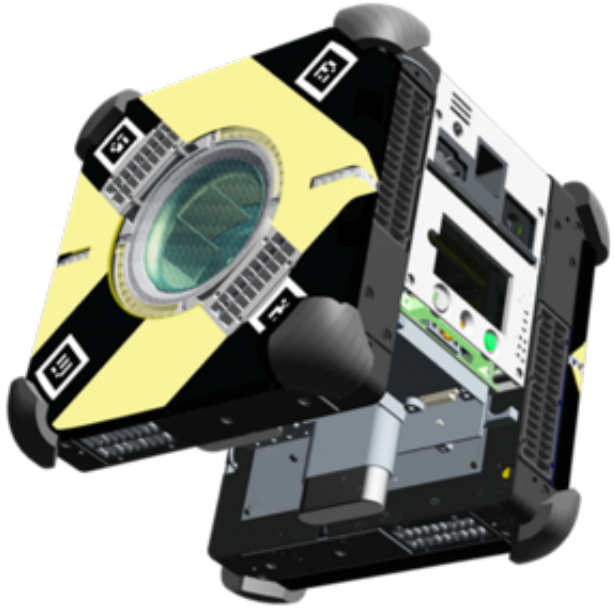
Oleg Alexandrov
Katie Browne
Maria Bualat
Brian Coltin
Earl Daley
Neil Davies
Lorenzo Fluckiger
Terry Fong
Jesse Fusco
Ryan Goetz
Yunkyung Kim
Dongmeng Li
John Love
Nghia Mai
Mike McIntyre
Don Morr
Ted Morse
Estrellina Pacis
Inwon Park
Greg Paulson
Hugo Sanchez
Trey Smith
Ernie Smith
Corey Snyder
The SPHERES Team
Andrew Symington
Omar Talavera
Vinh To
DW Wheeler
Shang Wu
Jongwoon Yoo

Alumni

Steve Battazzo
Jeff Blair
Jon Dewald
Jeff Feller
Ravi Gogna
Hyunjung Kim
Linda Kobayashi
Brian Koss
Alexandria Langford
Dong-Hyun Lee
Jason Lum
Andy Martinez
Blair Mclachlan
Zack Moratto
Robert Nakamura
Youngwoo Park
Cedric Priscal
Chris Provencher
Jay Torres
Allison Zuniga

Astrobee Equipment

- 3 free flyers, dock, spare ORUs on orbit
  - Honey (yellow)
  - Bumble (blue)
  - Queen (green)
- 3 free flyers, 2 docks (1 a flight spare), spares on ground
  - Melissa (pink)
  - B# (purple)
  - Killer (orange)



Research Scenario

	Sequence of Events
1	Prior to research activity, ground operator loads experimental software, free flyer does self-diagnostics.
2	Free flyer undocks and moves to experimental module.
3	Astronaut attaches external hardware to free flyer.
4	Ground operator sets up individual tests, and (optionally) astronaut initializes tests.
5	Free flyer perches to wait while astronaut pauses for EPO Event.
6	Astronaut detaches hardware and then free flyer returns to dock.

Contingency Fault Responses

- Unexpected obstacle/crew
  - Stop and wait for instructions
- Low battery
  - Alert and may autonomously return to dock
- LOS
  - Continue nominal operations
  - Long duration WiFi drop: may return to dock
- H/W & S/W failures
  - Halt operations and disable propulsion, articulation and active sensing

Astrobee Status

- Astrobee hardware delivery has slipped
  - On-dock date August 17, 2018
  - Targeting launch on Orbital-ATK 10 (November 8, 2018)
- Finalizing procurement
- Integration has begun (nozzles and core stack)
- Available to Guest Scientists:
  - Beta release of Flight Software/Simulator (v 0.3 coming soon)
  - Mechanical Payload ICD drawings
  - Initial draft of the Guest Science Guide

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Astrobee Integration

Y/Z Nozzles

X Nozzles

Cert Unit Stack