



Environmental Control & Life Support/Fire Safety Systems Maturation Team Status

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Background: Creation of SMT's in 2013



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Space Administration
Headquarters
Washington, DC 20546-0001



August 13, 2013

Reply to Attn of: Human Exploration and Operations Mission Directorate

TO: Directors, NASA Center

FROM: Associate Administrator for Human Exploration and Operations

SUBJECT: Establishment of NASA System Maturation Teams

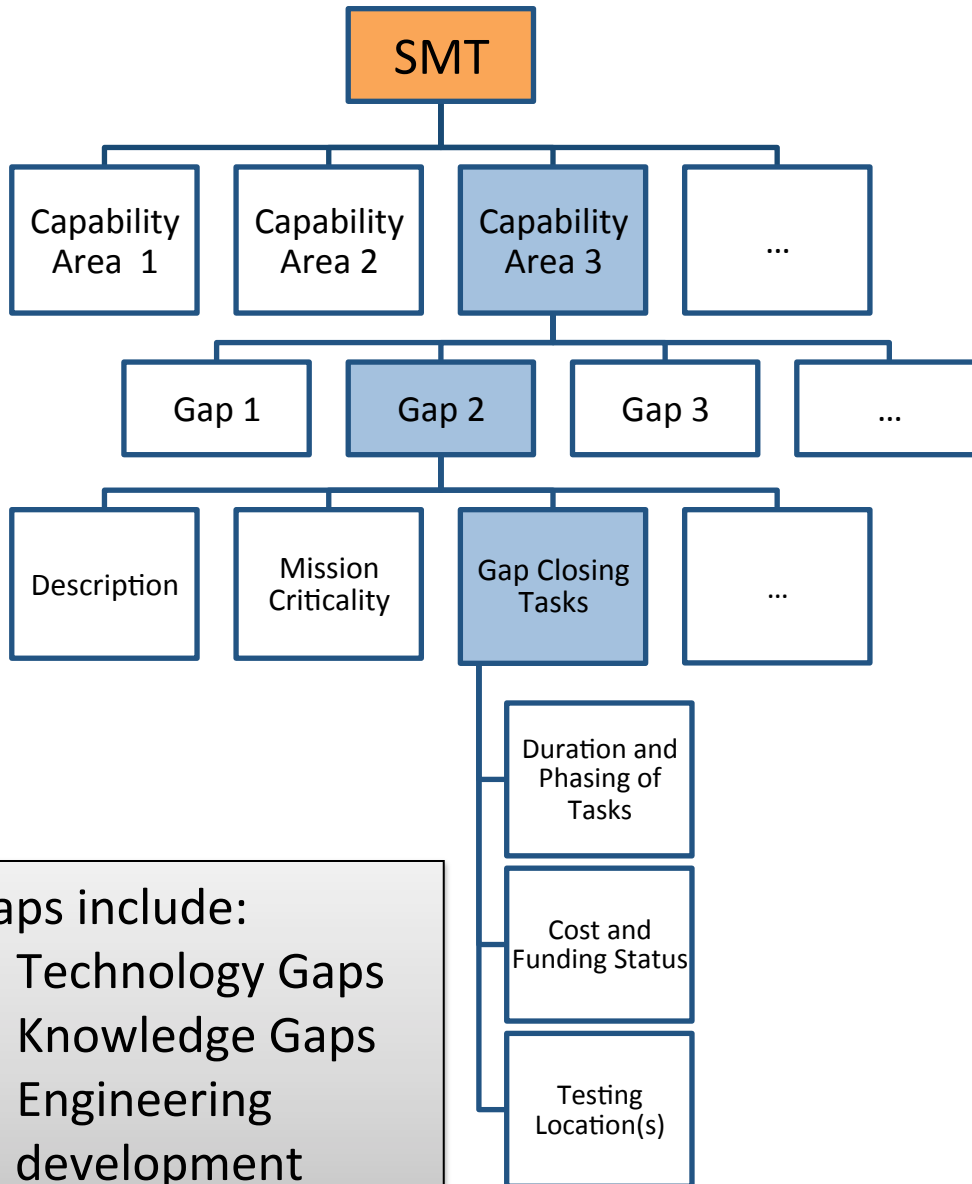
NASA Human Exploration and Operations Mission Directorate (HEOMD) is implementing a capability driven approach to future missions. This capability driven approach provides a framework through which architecture planning can be used to identify critical technology goals. This information, coordinated with the international partner critical technology goals identified in the Global Exploration Roadmap provides a strong foundation for HEOMD strategic planning and investment recommendations in preparation for future human space exploration. The Advanced Exploration Systems (AES) office within HEOMD has been tasked with leading a directorate wide team to develop system maturation roadmaps defining required improvements in design and operability for spaceflight systems to support the needs for future human space exploration. In addition, operation in a spaceflight environment such as on the International Space Station (ISS), when beneficial, should be used to prove the necessary reliability and operating parameters for future missions. These roadmaps will also provide a good foundation for the HEOMD input to the Office of the Chief Technologist technology development roadmap updates scheduled for release next year.

To guide this capability definition, HEOMD is establishing System Maturation Teams (SMT). The purpose of each multi-Center SMT will be to fully develop a roadmap that defines the activities required to advance critical capabilities, the means of demonstrating system performance, and the implementation planning to achieve the steps of the roadmap. These teams will also serve as ongoing subject matter expert teams that will be responsible for providing technical reviews of incoming proposals, recommendations for integrated ISS and ground tests, and inputs to the budget process for their respective areas. The teams will be augmented as required by tasks assigned. For example, international partner representatives may be added to the team to assess the capabilities from a global context. SMT status will be briefed periodically at HEOMD Directorate Program Management Council meetings across the year.

Recognizing that the expertise to accomplish this task is resident across the agency, the candidates to lead the SMTs, identified in the attachment to this letter, have been selected from across the centers. These candidates have been briefed on the goals of the SMT and are in the process of identifying their full team membership across the agency. I request your

- **The purpose of each multi-center SMT is to fully develop a roadmap that defines**
 - Measures of system performance required to execute future missions
 - The activities required to advance critical capabilities
 - The means of demonstrating system performance
 - The implementation planning to achieve the steps of the roadmap
- **The teams also serve as ongoing subject matter expert teams that are responsible for**
 - Providing technical reviews of incoming proposals
 - Recommendations for integrated ISS and ground tests
 - Inputs to the budget process for their respective areas

System Maturation Teams



System Maturation Team (SMT)
Autonomous Mission Operations (AMO)
Communications and Navigation (Comm/Nav)
Crew Health & Protection - Radiation
Environmental Control and Life Support Systems and Environmental Monitoring (ECLSS-EM)
Entry, Descent and Landing (EDL) Extravehicular Activities (EVA)
Fire Safety
Human-Robotic Mission Operations
In-Situ Resource Utilization (ISRU)
Power and Energy Storage
Propulsion
Thermal Systems
Avionics (Discipline Team)
Structures, Mechanisms, Materials and Process (SMMP) (Discipline Team)

Human Space Exploration Phases From ISS to the Surface of Mars



Today

Phase 0: Exploration Systems
Testing on ISS

Ends with testing,
research and
demos complete*

Asteroid Redirect-Crewed
Mission Marks Move from
Phase 1 to Phase 2

Phase 1: **Cislunar Flight
Testing** of Exploration
Systems

Ends with one year
crewed Mars-class
shakedown cruise

Phase 2: **Cislunar Validation**
of Exploration Capability

Phase 3: Crewed Missions
Beyond Earth-Moon System

Phase 4a: Development
and robotic
preparatory missions

Phase 4b: Mars
Human Landing
Missions



Planning for the details and specific
objectives will be needed in ~2020

* There are several other
considerations for ISS end-of-life

Mid-2020s

2030

Preliminary Top-Level Phase 0 -1 - 2 Objectives

Phase 0: Exploration Research and Systems Testing on ISS

- Test Mars-capable **habitation systems** – ECLS, environmental monitoring, crew health equipment, exploration generation EVA suit, fire detection/suppression, radiation monitoring
- Complete **human health & performance** research and risk reduction activities
- Demonstrate **exploration related technologies and operations**
 - Autonomous crew operations
 - Docking, prox ops

enables

- Robotic manipulation technology and techniques demonstrations
- Remote presence technology development and demonstrations
- Earth/space science
- Enable development of LEO commercial market

Phase 1: Cislunar Flight Testing of Exploration Systems

- Demonstrate that **SLS and launch processing systems** can insert both Orion and comanifested payloads into cislunar space
- Demonstrate that **Orion and mission operations** can conduct crewed missions in cislunar space at least for 21 days
- Demonstrate **Mars extensible systems and mission operations** that reduce risk for future deep space missions (with EVA) beyond 21 days

enables

- Validate cislunar as staging orbits
- Use of high power SEP for deep space missions
- Asteroid related origins of the solar system science objectives
- Demonstrate real-time robotic lunar surface activities
- In situ resource utilization demonstrations

Phase 2: Cislunar Validation of Exploration Capability

- Validate **Mars class habitation** and habitation system functionality and performance
- Validate **Mars class human health and performance**
- Validate operational readiness to leave Earth-Moon system via **one year+ “shakedown cruise”** (no resupply/crew exchanges, limited ground interaction, etc.)

enables

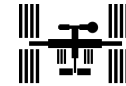
- Origins of the universe, lunar rover volatile sample return
- Other scientific or research objectives?

Specific Habitation Systems Objectives



Habitation Systems Elements

The systems, tools, and protections that allow humans to live and work in space and on other worlds.



T O D A Y
ISS



F U T U R E
Deep Space

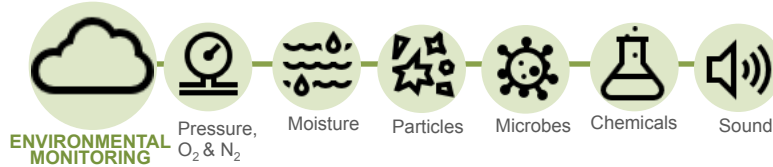
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42% O₂ Recovery from CO₂
90% H₂O Recovery
< 6 mo mean time before failure (for some components)

75%+ O₂ Recovery from CO₂
98%+ H₂O Recovery
>30 mo mean time before failure

2



Limited, crew-intensive on-board capability
Reliance on sample return to Earth for analysis

On-board analysis capability with no sample return
Identify and quantify species and organisms in air & water

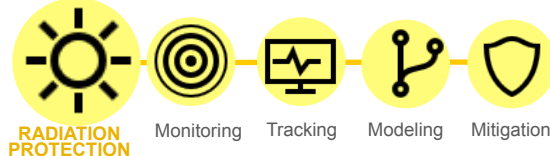
3



Bulky fitness equipment
Limited medical capability
Frequent food system resupply

Smaller, efficient equipment
Onboard medical capability
Long-duration food system

4



Node 2 crew quarters (CQ) w/ polyethylene reduce impacts of proton irradiation.
RAD, REM – real-time dosimetry, monitoring, tracking, model validation & verification
TEPC, IVTEPC – real-time dosimetry
CPD, RAM – passive dosimeters

Solar particle event storm shelter, optimized position of on-board materials and CQ
Distributed REM/HERA system for real-time monitoring & tracking
CPAD – real-time dosimeter

5



Large CO₂ Suppressant Tanks
2-cartridge mask
Obsolete combustion prod. sensor
Only depress/repress clean-up

Unified, effective fire safety approach across small and large architecture elements

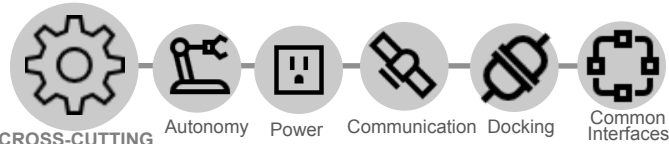
6



Manual scans, displaced items
Disposable cotton clothing
Packaging disposed
Bag and discard

Automatic, autonomous RFID
Long-wear clothing & laundry
Bags/foam repurposed w/3D printer
Resource recovery, then disposal

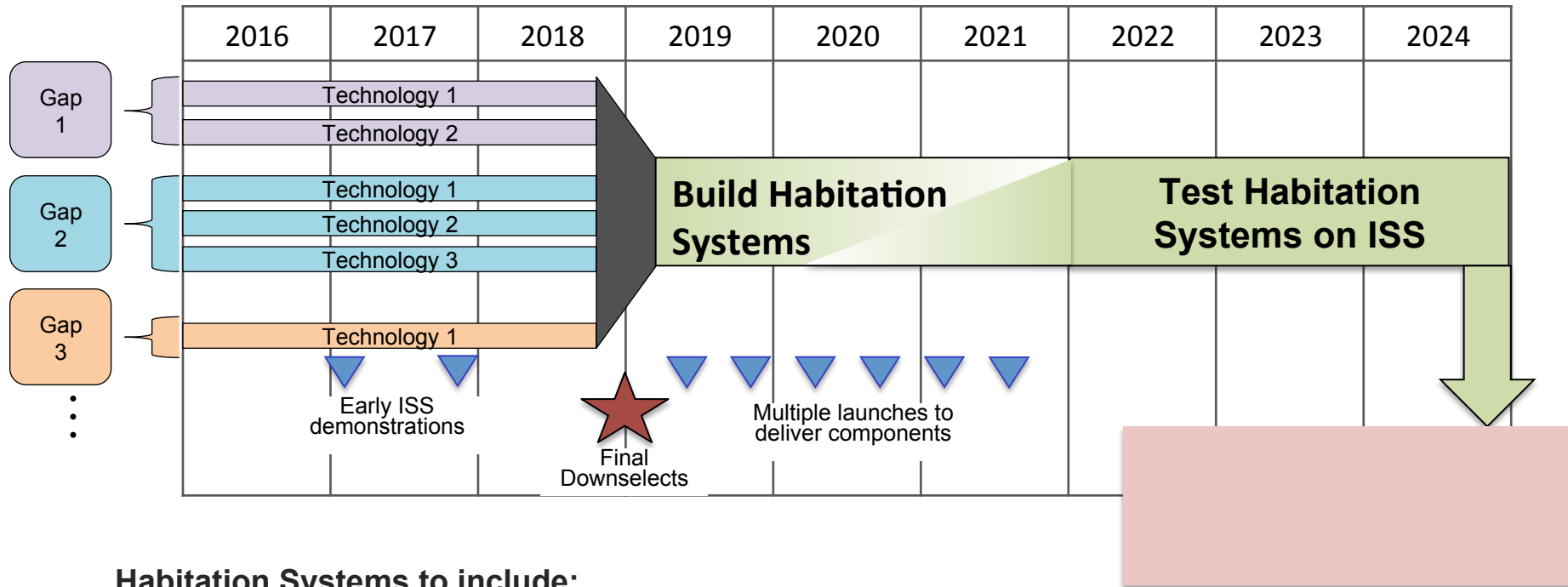
7



Minimal on-board autonomy
Near-continuous ground-crew comm
Some common interfaces, modules controlled separately

Ops independent of Earth & crew
Up to 40-minute comm delay
Widespread common interfaces, modules/systems integrated

Phase 0 – Habitation Systems Testing on ISS



Habitation Systems to include:

- 4-rack Exploration ECLSS and Environmental Monitoring hardware
- Fire Safety studies and end-to-end detection/suppression/cleanup testing in Saffire series (Cygnus)
- Mars-class exercise equipment
- On-board medical devices for long duration missions
- Long-duration food storage
- Radiation monitoring and shielding
- Autonomous crew operations



ECLSS & Environmental Monitoring

Robyn Gatens

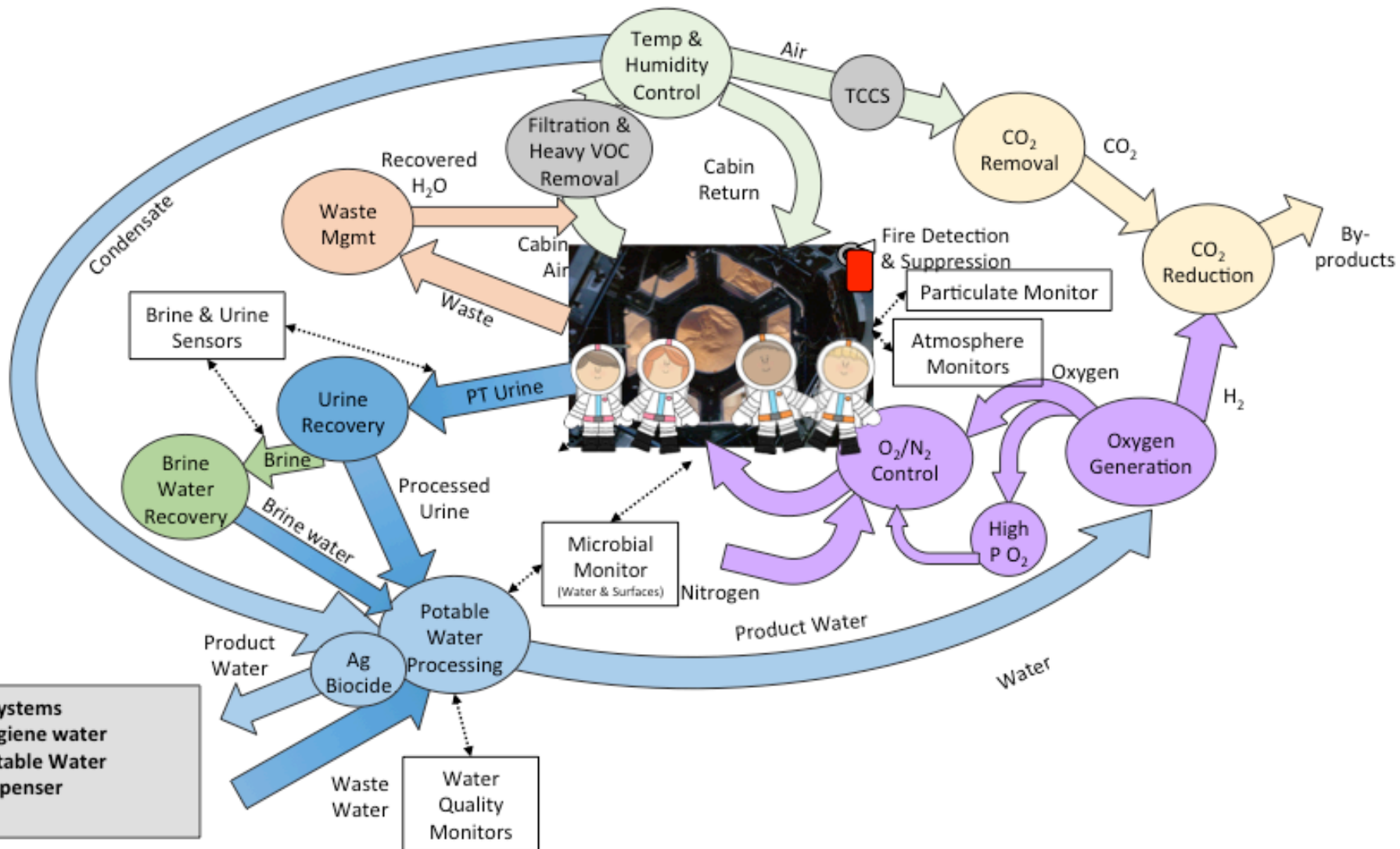
Mars is Harder for ECLSS

- Regular resupplies of makeup consumables, spare parts
 - 42% air loop closure
 - 90% water loop closure
 - 6 months of spares
- Return, analyze samples on Earth
- Emergency crew return capability
- Trash disposal

- No resupply
 - 75% air loop closure
 - 98% water loop closure
 - 3 years of spares
- On orbit monitoring
- No emergency crew return
- No trash disposal



Exploration ECLSS Diagram

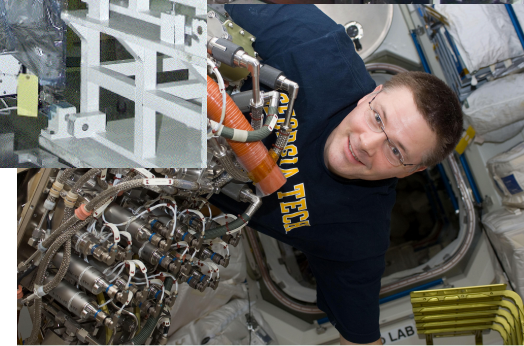
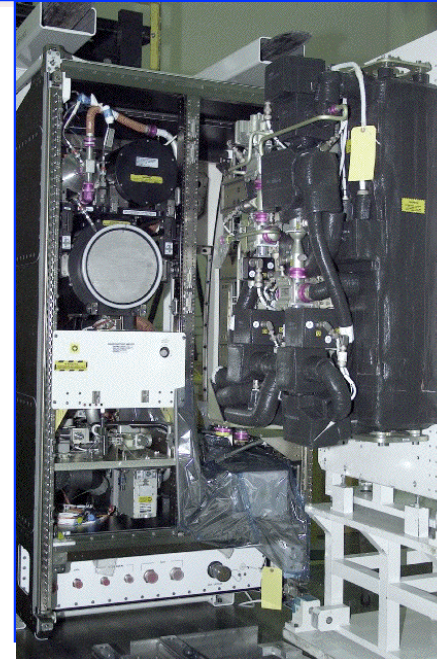
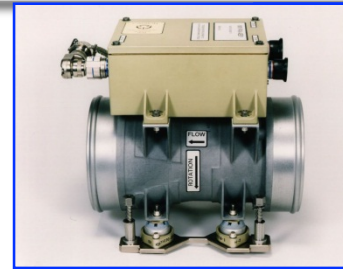


Current ISS Capabilities and Challenges

Atmosphere Management



- Circulation
 - ISS: Fans (cabin & intermodule), valves, ducting, mufflers, expendable HEPA filter elements
 - **Challenges: Quiet fans, filters for surface dust**
- Remove CO₂ and contaminants
 - ISS: Regenerative zeolite CDRA, supports ~2.3 mmHg ppCO₂ for 4 crew. MTBF <6 months. Obsolete contaminant sorbents.
 - **Challenges: Reliability, ppCO₂ <2 mmHg, commercial sorbents**
- Remove humidity
 - ISS: Condensing heat exchangers with anti-microbial hydrophilic coatings requiring periodic dryout, catalyze siloxane compounds.
 - **Challenge: Durable, inert, anti-microbial coatings that do not require dry-out**
- Supply O₂
 - ISS: Oxygen Generation Assembly (H₂O electrolysis, ambient pressure); high pressure stored O₂ for EVA
 - **Challenge: Provide high pressure/high purity O₂ for EVA replenishment & medical use**
- Recovery of O₂ from CO₂
 - ISS: Sabatier process reactor, recovers 42% O₂ from CO₂
 - **Challenge: >75% recovery of O₂ from CO₂**

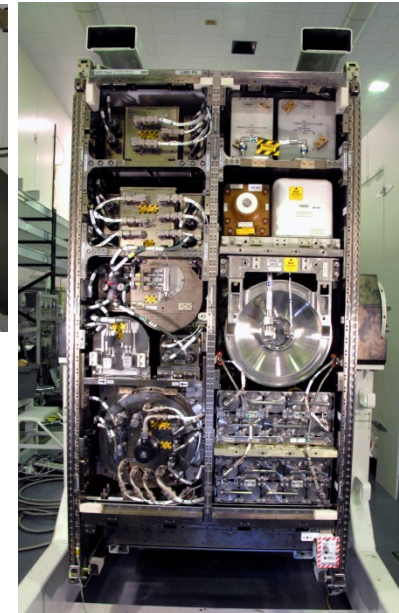
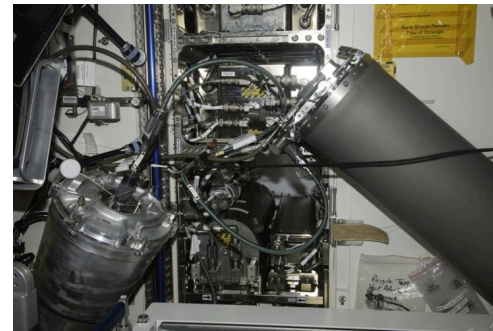
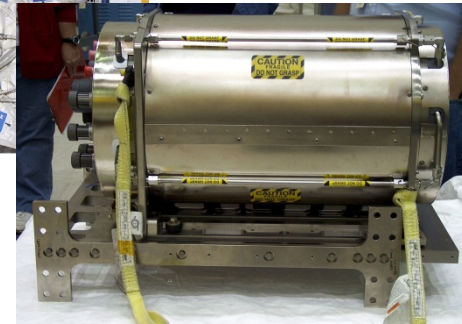


Current ISS Capabilities and Challenges

Water Management



- Water Storage & biocide
 - ISS: Bellows tanks, collapsible bags, iodine for microbial control
 - Challenges: Common biocide (silver) that does not need to be removed prior to crew consumption; dormancy
- Urine Processing
 - ISS: Urine Processing Assembly (vapor compression distillation), currently recovers 80% (brine is stored for disposal)
 - Challenges: 85-90% recovery (expected with alt pretreat formulation just implemented); reliability; recovery of urine brine water
- Water Processing
 - ISS: Water Processor Assembly (filtration, adsorption, ion exchange, catalytic oxidation, gas/liquid membrane separators), 100% recovery, 0.11 lbs consumables + limited life hw/lb water processed.
 - Challenges: Reduced expendables; reliability



Current ISS Capabilities and Challenges

Waste Management



- Logistical Waste (packaging, containers, etc.)
 - ISS: Gather & store; dispose (in re-entry craft)
 - **Challenge: Reduce &/or repurpose**
- Trash
 - ISS: Gather & store; dispose (in re-entry craft)
 - **Challenge: Compaction, stabilization, resource recovery**
- Metabolic Waste
 - ISS: Russian Commode, sealed canister, disposal in re-entry craft
 - **Challenge: Long-duration stabilization, potential resource recovery, volume and expendable reduction**



Current ISS Capabilities and Challenges

Environmental Monitoring



- Water Monitoring

- ISS: On-line conductivity; Off-line total organic carbon, iodine; Samples returned to earth for full analysis
- Challenge: On-orbit identification and quantification of specific organic, inorganic compounds.

- Microbial

- ISS: Culture-based plate count, no identification, 1.7 hrs crew time/sample, 48 hr response time; samples returned to earth.
- Challenge: On-orbit, non culture-based monitor with identification & quantification, faster response time and minimal crew time

- Atmosphere

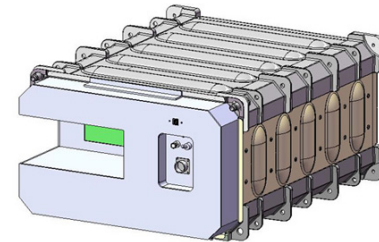
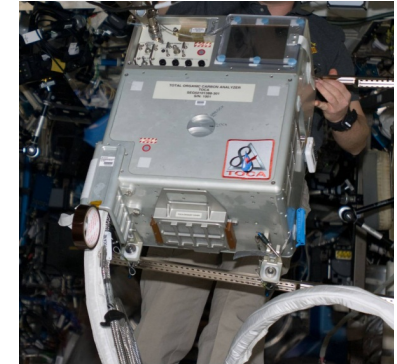
- ISS: Major Constituent Analyzer (mass spectrometry – 6 constituents); COTS Atmosphere Quality Monitors (GC/DMS) measure ammonia and some additional trace gases; remainder of trace gases via grab sample return; Combustion Product Analyzer (CSA-CP, parts now obsolete)
- Challenges: On-board trace gas capability that does not rely on sample return, optical targeted gas analyzer

- Particulate

- ISS: N/A
- Challenge: On-orbit monitor for respiratory particulate hazards

- Acoustic

- SOA: Hand held sound level meter, manual crew assays
- Challenge: Continuous acoustic monitoring with alerting

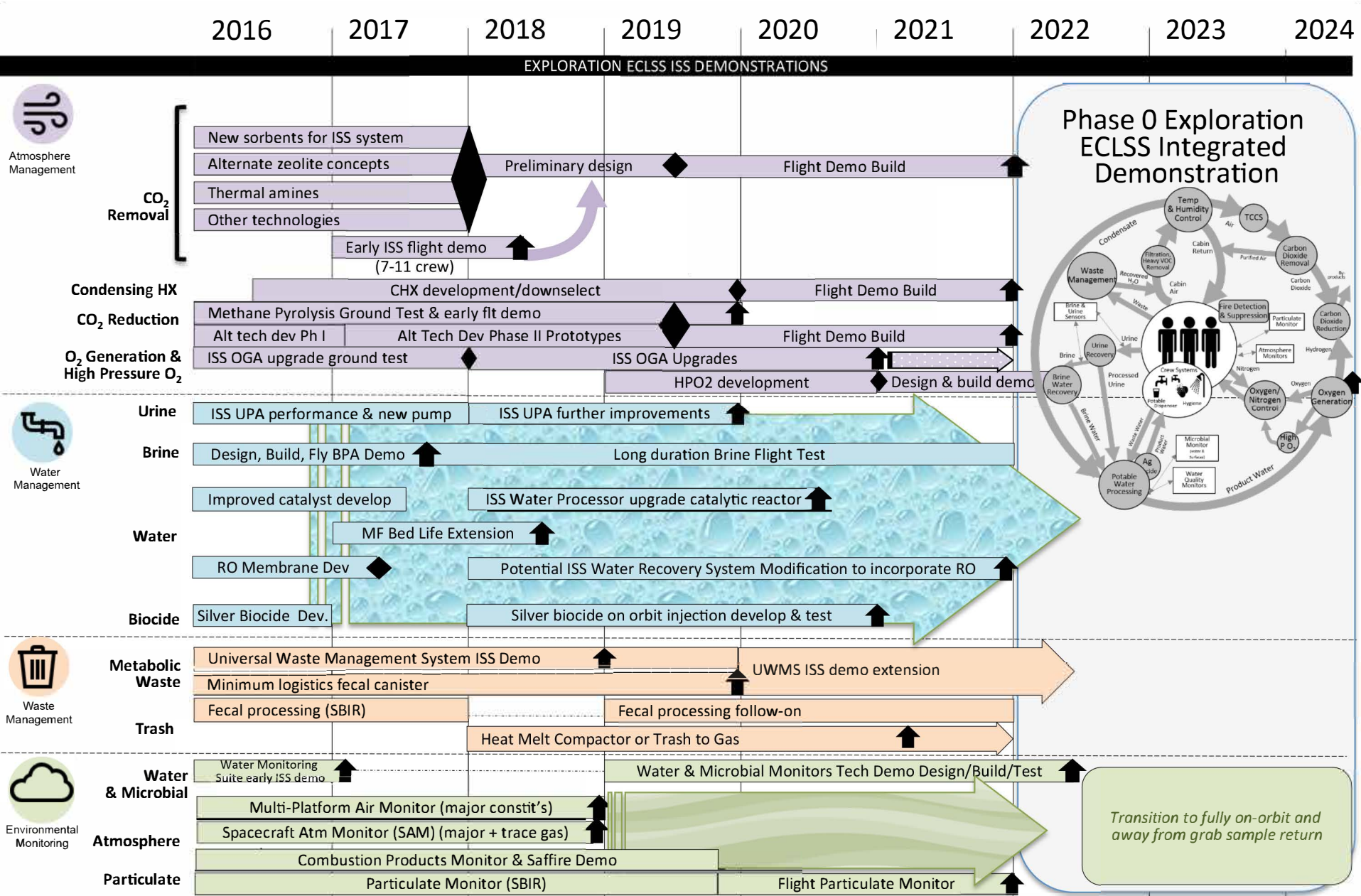


ECLSS & Environmental Monitoring Capability Gaps



Function	Capability Gaps	Gap Criticality: 5 = high	Gap criticality as applicable to transit Hab	Orion Need
CO ₂ Removal	Bed and valve reliability; ppCO ₂ <2 mmHg		5	
O ₂ recovery from CO ₂	Recover >75% O ₂ from CO ₂		5	
Urine brine processing	Water recovery from urine brine >85%		5	
Metabolic solid waste collection	Low-mass, universal waste collection		5	X
Trace Contaminant Control	Replace obsolete sorbents w/ higher capacity; siloxane removal		4	X
Condensing Heat Exchanger	Durable, chemically-inert hydrophilic surfaces with antimicrobial properties		4	
Water microbial control	Common silver biocide with on-orbit redosing		4	
Contingency urine collection	Backup, no moving parts urine separator		4	X
Urine processing	Reliability, 85% water from urine, dormancy survival		4	
Atmosphere monitoring	Small, reliable atmosphere monitor for major constituents, trace gases, targeted gases		4	X
Water monitoring	In-flight identification & quantification of species in water		4	
Microbial monitoring	Non-culture based in-flight monitor with species identification & quantification		4	
O ₂ generation	Smaller, reduced complexity, alternate H ₂ sensor		3	
High pressure O ₂	High pressure (3000 psi) O ₂ for EVA/on-demand O ₂ supply for contingency medical		3	
Wastewater processing (WPA)	Reliability (ambient temp, reduced pressure catalyst), reduced expendables, dormancy survival		3	
Non-metabolic solid waste	Volume reduction, stabilization, resource recovery		3	
Particulate monitoring	On-board measurement of particulate hazards		3	
Particulate Filtration	Surface dust pre-filter; regen filter		2	
Atmosphere circulation	Quiet fans		2	
Logistics Reduction	10:1 volume reduction logistical and clothing		2	
Metabolic solid waste treatment	Useful products from metabolic waste		1	

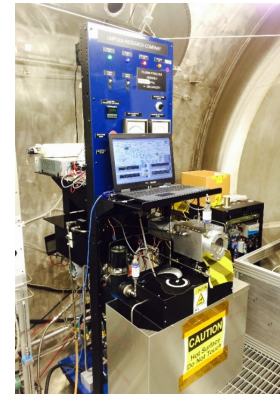
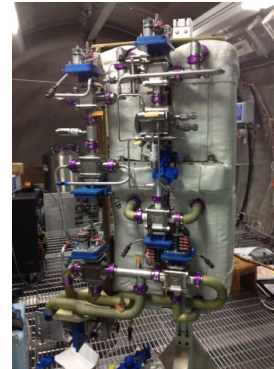
Exploration ECLSS Roadmap



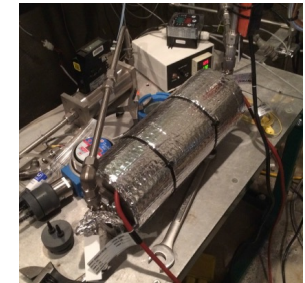
Progress – Atmosphere Management



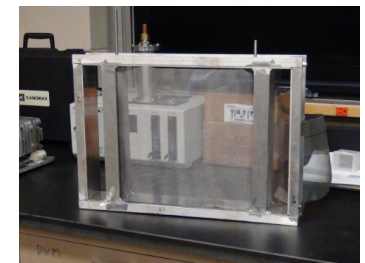
- **CO₂ Removal**
 - improved sorbents
 - alternate technology development
- **Oxygen Generation & High Press O₂**
 - testing to reduce complexity
 - high pressure cell stack development
 - oxygen concentrator development
- **Oxygen Recovery/CO₂ Reduction**
 - new technology development
- **Condensing Heat Exchanger**
 - improved coatings development
- **Trace Contaminant Control**
 - alternate commercial sorbent testing
 - integrated architecture
- **Particulate Filtration**
 - pre-filter and regenerable filter development



3rd Gen
PPA



Hydrogen Recombiner



Scrolling Screen Pre-filter

Progress – Water Management



- **Urine processing**

- new pretreat formula on ISS improves recovery to 85-90%
- pump reliability improvements

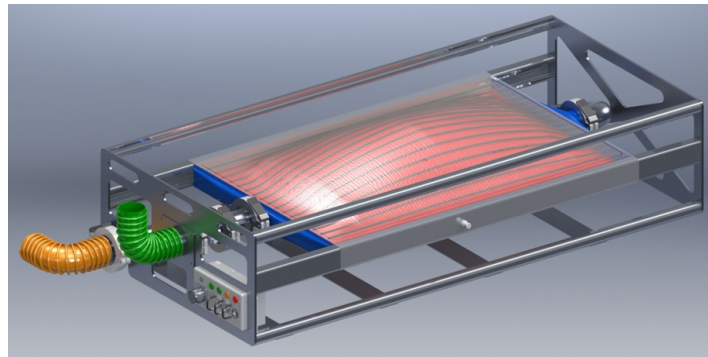
- **Water processing**

- improved catalyst development
- operational filter life extension
- alternate technology/reverse osmosis testing & trade



- **Brine processing**

- ISS flight demonstration in development – flies in 2017



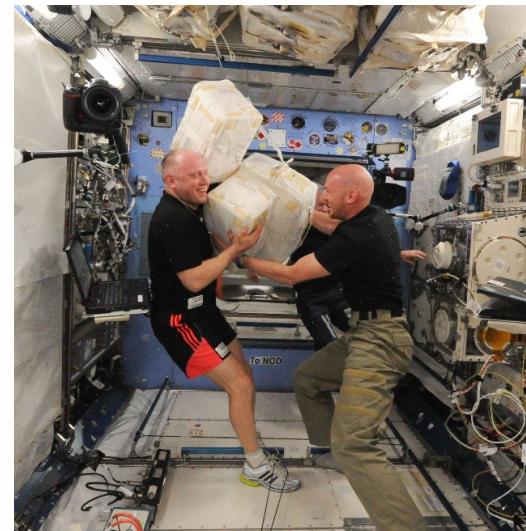
- **Silver biocide**

- development of on orbit injection capability

Progress – Waste Management



- **Commode**
 - universal waste management system for ISS demo & Orion
 - minimum mass fecal container development
- **Trash management**
 - heat melt compactor development
 - trash to gas development
- **Fecal processing**
 - torrefaction SBIR development
- **Logistics Reduction**
 - long wear clothing demonstrated on ISS
 - repurposing of packaging and cargo bags
 - RFID-enabled logistics management planned for ISS



Progress – Environmental Monitoring



- **Atmosphere Monitors**

- micro GC/MS for major constituents and trace gases ISS tech demo planned
- laser-based monitors for combustion products and targeted gases (planned for Saffire demonstration)
- improved mass spec for ISS & Orion use

- **Water Monitor**

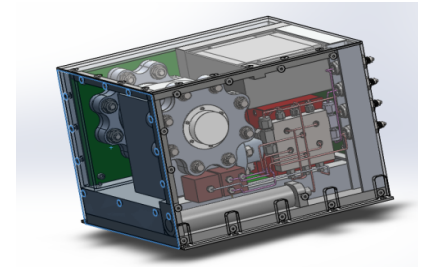
- ISS demo water monitoring suite on SpX-9
- front end to atmosphere monitor for water samples

- **Microbial Monitor**

- PCR (Razor) flight demonstration (SpX-9)
- DNA sequencer flight demonstration

- **Particulate Monitor**

- aerosol sampler flight demonstration (OA-5)
- SBIR particulate monitor development



SAM



Thermophoretic Sampler
(TPS)

(Credit: RJ Lee Group)



Fire Safety

Gary A. Ruff

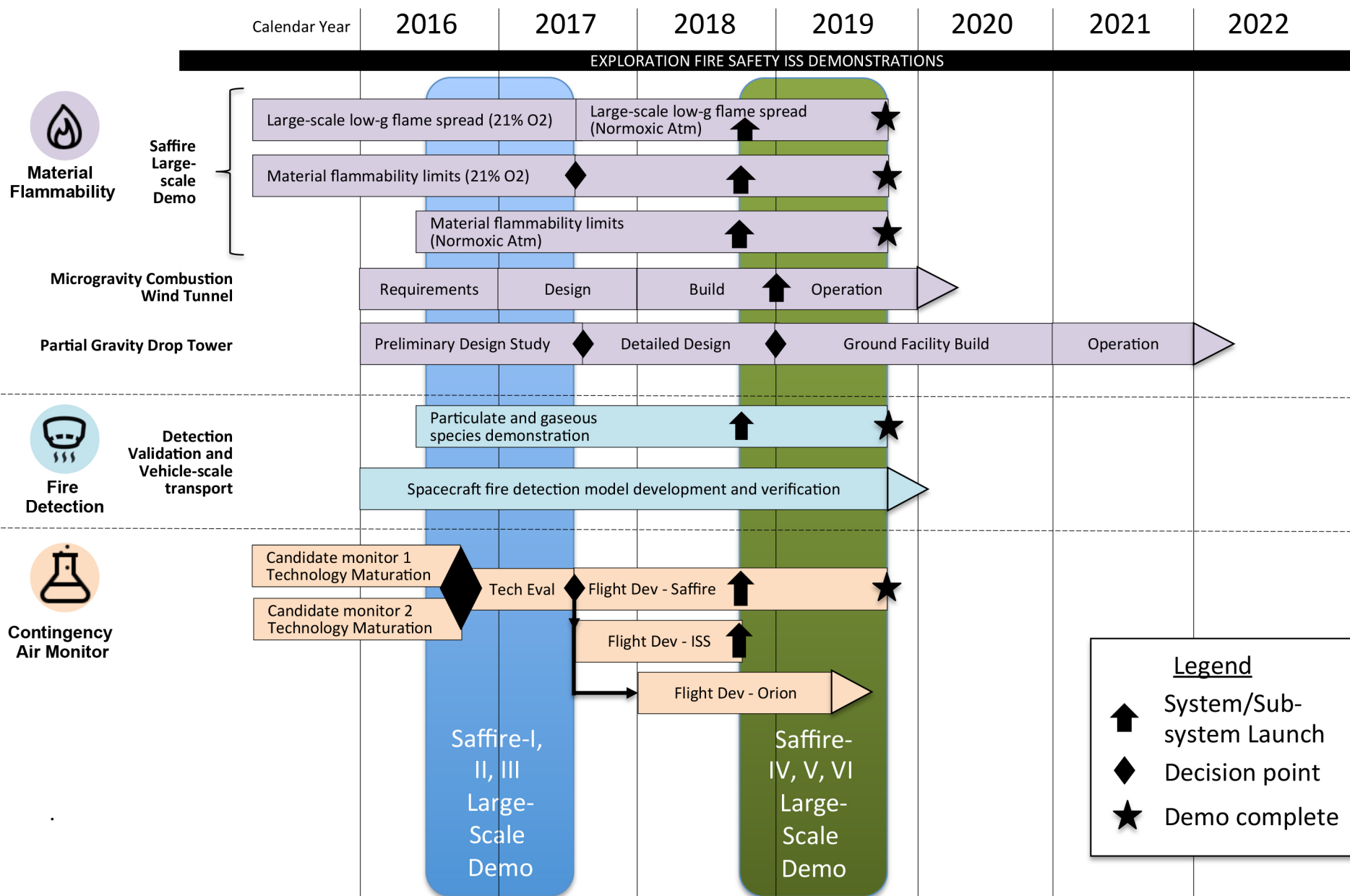
Fire Safety Capability Gaps



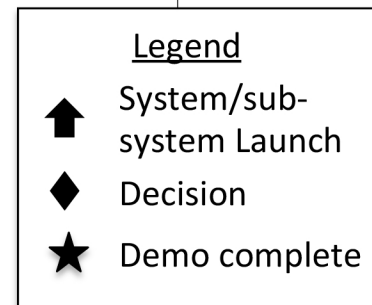
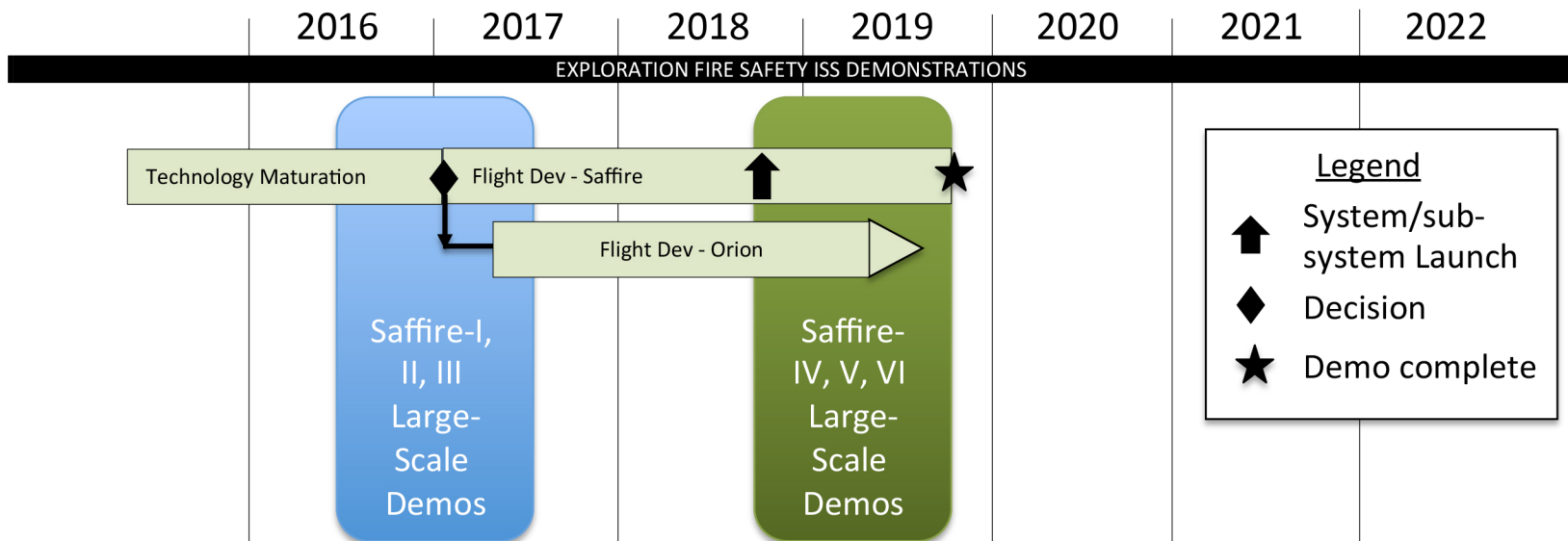
Function	Capability Gaps	Gap criticality as applicable to mg transit Hab	Orion Need
Fire Suppression	ECLSS-compatible and rechargeable fire suppression; compatible with small cabin volumes.	5	X
Emergency Crew Mask	Single filtering cartridge mask (fire, ammonia, toxic spill), compatible with small cabin volumes (no O2 enrichment)	5	X
Combustion Product Monitoring	Contingency air monitor for relevant chemical markers of post-fire cleanup; CO, CO ₂ , HF, HCl, HCN; battery-operated; hand-held calibration duration 1-5 years; survives vacuum exposure.	5	X
Low- and partial - gravity material flammability	Identify material flammability limits in low-g environment	4	X
Post-fire cleanup/ smoke eater	Contingency air purifier for post-fire and leak cleanup; Reduce incident response time by 75% compared to getting in suits and purging atm	4	X
Fire Scenario Modeling and Analysis	Definition of a realistic spacecraft fire to size	3	X
Fire Detection	Early fire detection; particle size discrimination (false alarms)	2	X

Gap
Criticality:
5 = high
1 = low

Exploration Fire Safety Roadmap



Exploration Fire Safety Roadmap



Ground-Based Development



Emergency Crew Mask

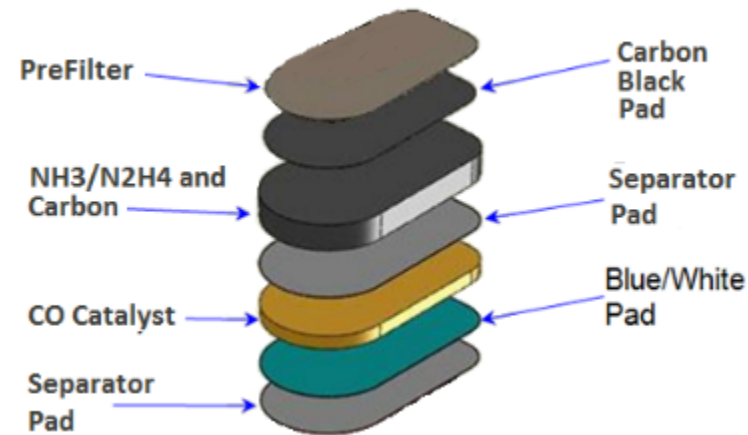
- Joint NESC/Commercialization Readiness Program (CRP)-funding to develop a single, rigidly mounted cartridge for emergency response
 - Protect against either a small-scale fire or 30,000 ppmv (3%) ammonia for >15 min
 - TDA, Inc. funded on Phase III SBIR to develop sorbents



Cartridge is 8 cm wide;
sorbent bed is 3 cm deep.

Post-fire/leak clean-up (Smoke-eater)

- Smoke-eater system is being developed concurrently with the emergency crew mask
 - Contains the same adsorber stack but is larger than the crew mask
- Self-contained unit includes a fan
- Demo in Saffire-IV-VI will only include CO catalyst and sized for the Cygnus vehicle and anticipated fire in Saffire



Fire Suppression

- Determined amount of water to extinguish WSTF battery fire
- Developing light-weight extinguisher tanks based on ISS fine water mist (FWM) portable fire extinguisher (PFE) technology
 - Welded titanium with in internal rubber bladder
 - Carbon-over-wrapped pressure vessel
- Will evaluate performance of prototype systems



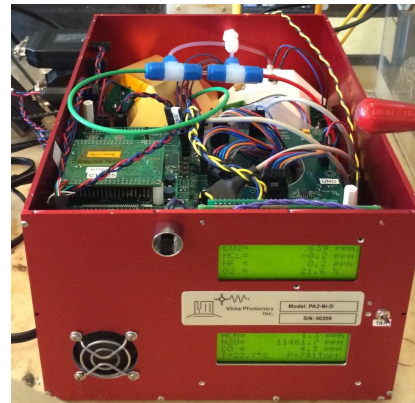
Discharge against the stored energy battery fire (left) and prior to discharge against an open cabin fire (right).

*Engineering Development
Unit of an ISS FWM PFE*

Progress – Combustion Product Monitoring



- Technology development for candidate combustion product monitors has been on-going for several years
 - Two similar technologies have reached maturity to be considered for downselect
- Both technologies measure O_2 , CO_2 , H_2O , CO , HCN , HF , HCl
- Current effort has been to decrease mass, volume, and power to meet ISS and Orion operational requirements
- Prototype units will be delivered to NASA-GRC at the end of July for evaluation
 - Component hardening, vibration testing, evaluation with calibration gases (JSC) and pyrolysis products (GRC)
- Down-select in September 2016
 - ISS/Orion flight hardware development
 - Incorporation into Saffire-IV-VI



Previous generation
CPM technologies
(January 2016).



Saffire-I, II, & III Overview



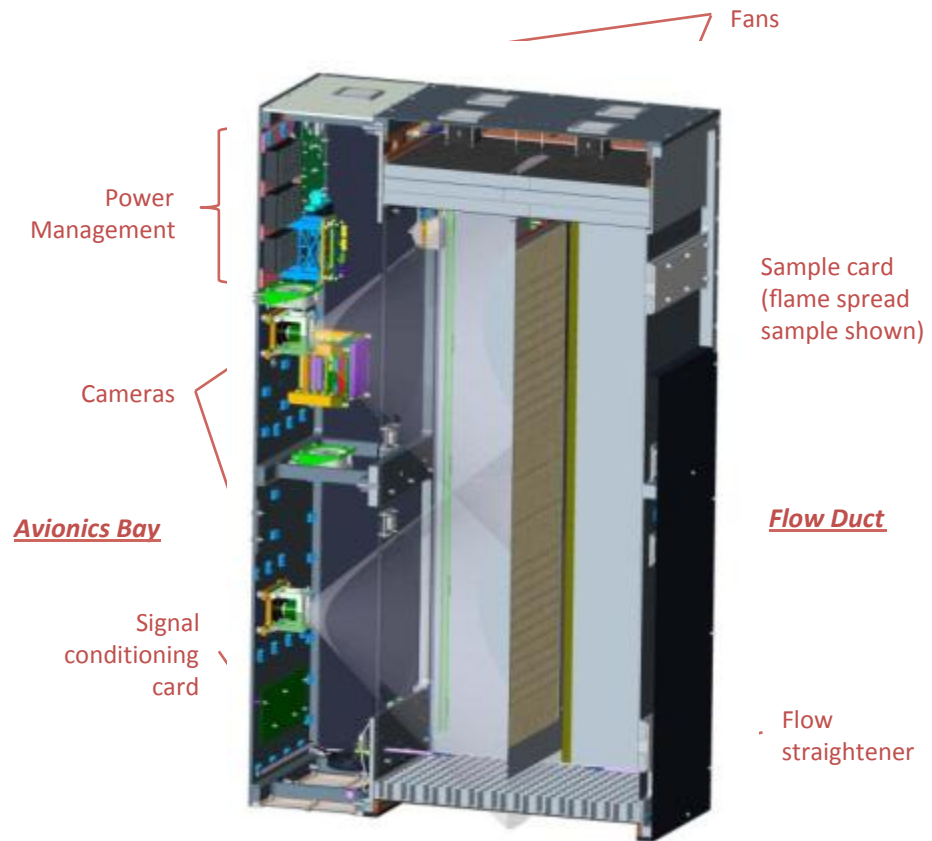
Needs:

- ◆ *Low-g flammability limits for spacecraft materials*
- ◆ *Definition of realistic fires for exploration vehicles*
 - *Fate of a large-scale spacecraft fire*

Objectives:

- ◆ *Saffire-I: Assess flame spread of large-scale microgravity fire (spread rate, mass consumption, heat release)*
- ◆ *Saffire-II: Verify oxygen flammability limits in low gravity*
- ◆ *Saffire-III: Same as Saffire-I but at different flow conditions.*

- *Data obtained from the experiment will be used to validate modeling of spacecraft fire response scenarios*
- *Evaluate NASA's normal-gravity material flammability screening test for low-gravity conditions.*



Saffire module consists of a flow duct containing the sample card and an avionics bay. All power, computer, and data acquisition modules are contained in the bay. Dimensions are approximately 53- by 90- by 133-cm

Saffire-I Launch: March 22



- **Successful launch of Saffire-I onboard Cygnus OA-6 (SS Rick Husband) on March 22**
 - Orbital ATK reported that OA-6 had a nominal ascent.
 - Spacecraft Mission Director reported to the Saffire team “Vehicle is good. PCM is good. All inhibits in place. Enjoy the ride.”



Launch of OA-6 on March 22 carrying Saffire-I



Saffire-I photograph taken by the ISS crew following initial ingress to the PCM



- ◆ **OA-6 Pressurized Cargo Module (PCM) berthed to the ISS on Saturday, March 26 with crew ingress into the PCM on March 27**

Saffire-I Operations: June 14-20, 2016



NASA and Orbital ATK teams at MCC-Dulles (above) and Flight Operations-GRC (right) conducted and monitored Saffire-I operations

- ◆ **Operations received considerable coverage on social media**
 - NASA GRC and Advanced Exploration Systems Division (AES)

- ◆ **OA-6 unberthed from the ISS at 9:30 a.m. EDT on June 22**
- ◆ **Saffire-I was powered on at 2:23 p.m.**
- ◆ **RUN command was sent at 4:41 p.m.**
 - Ignition at 4:44 p.m.
- ◆ **Cygnus smoke detector readings received at 4:52 p.m.**



SAFFIRE in the Media

- **Traditional Media:**

- Covered by **315** media outlets worldwide
- Includes: PBS News Hour, CBS News, USA Today Online, Aviation Week and Popular Mechanics Online

- **Social Media:**

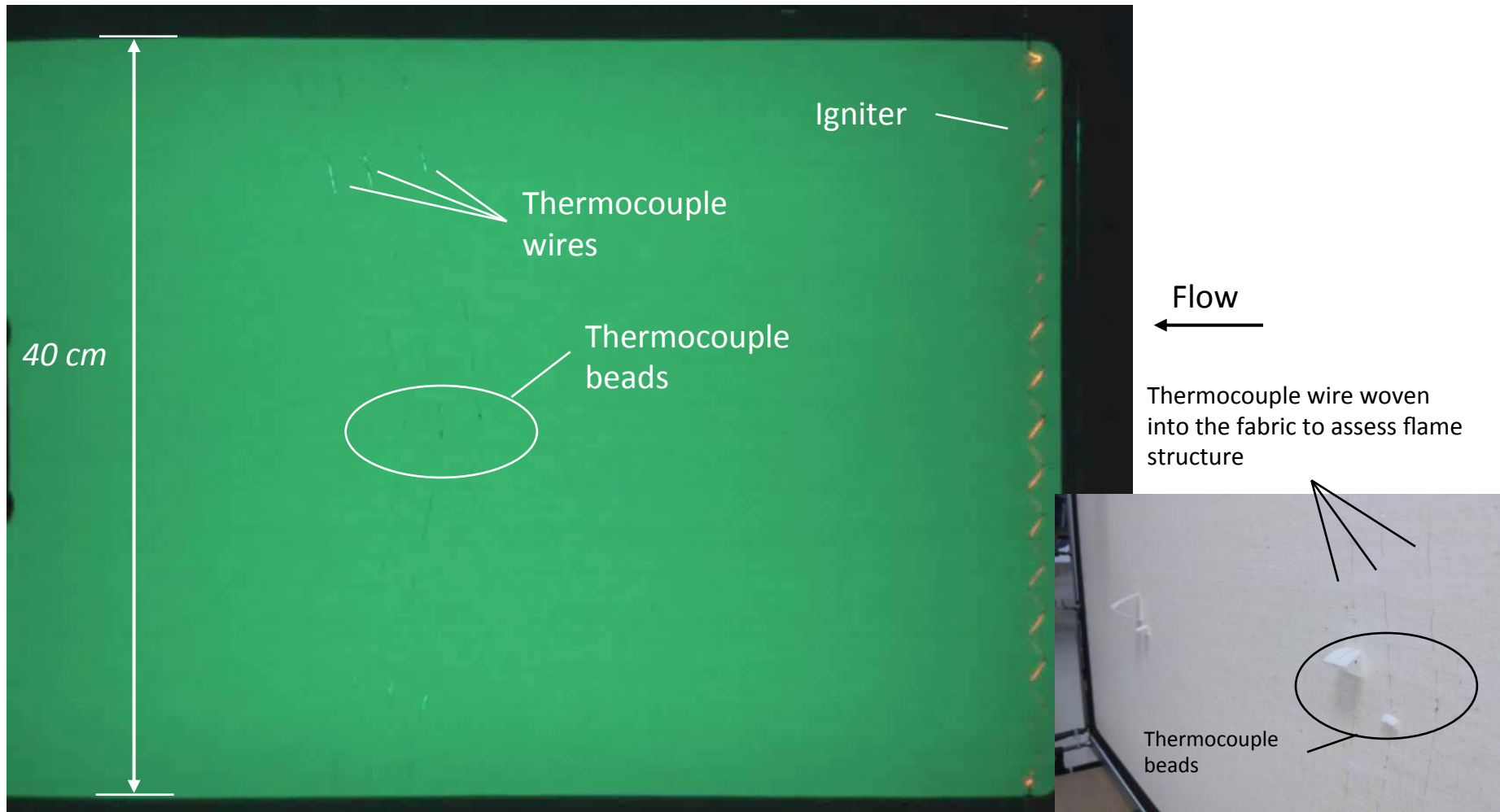
- **20** total posts from NASA accounts (Facebook, Twitter, Instagram, LinkedIn)
- **392,102** total engagements (likes, comments and shares)
- **61.5M** people reached

Data compiled June 14-30, 2016

JOURNEY TO MARS

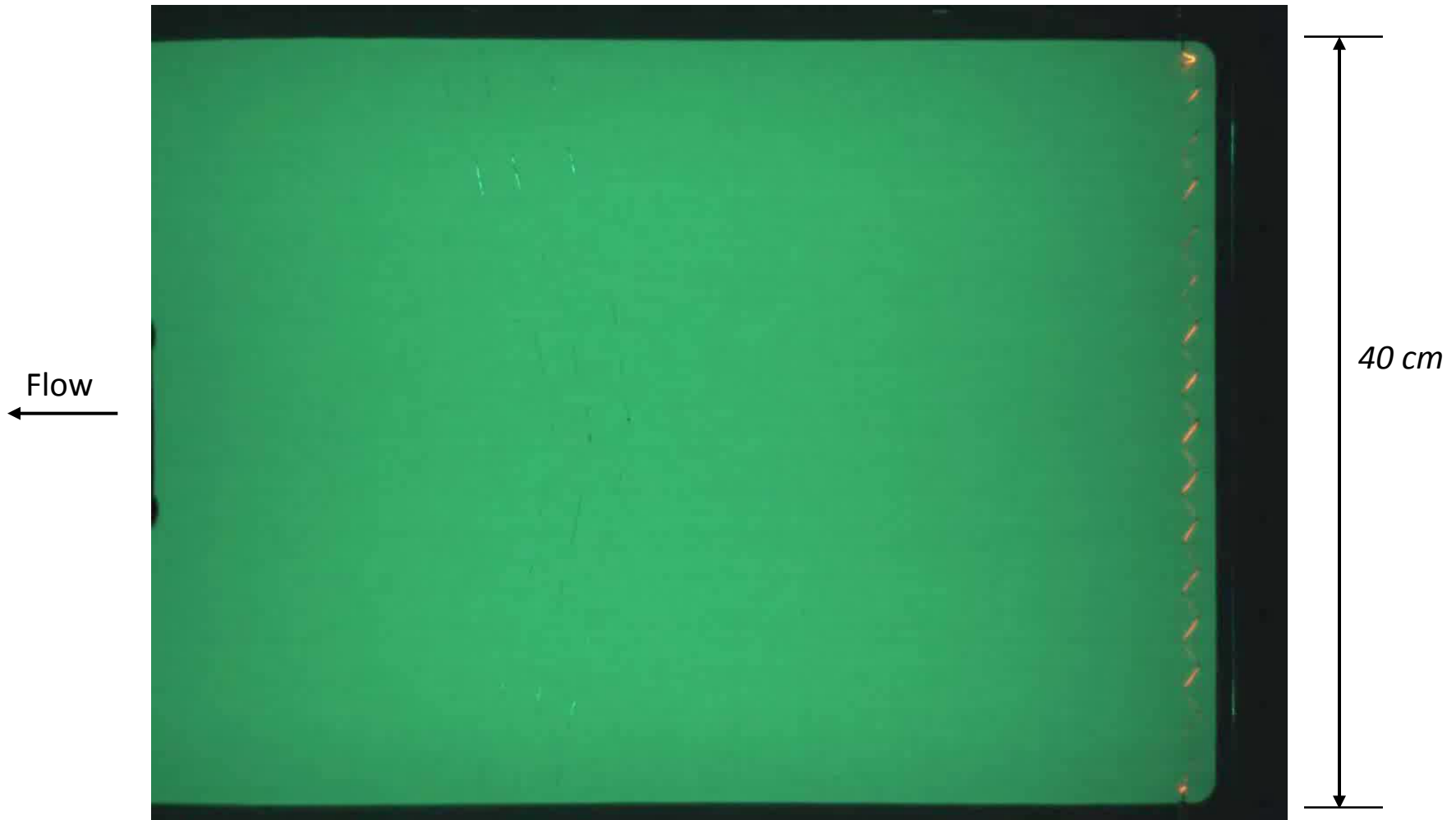


Saffire-I Results - Concurrent Flow Igniter



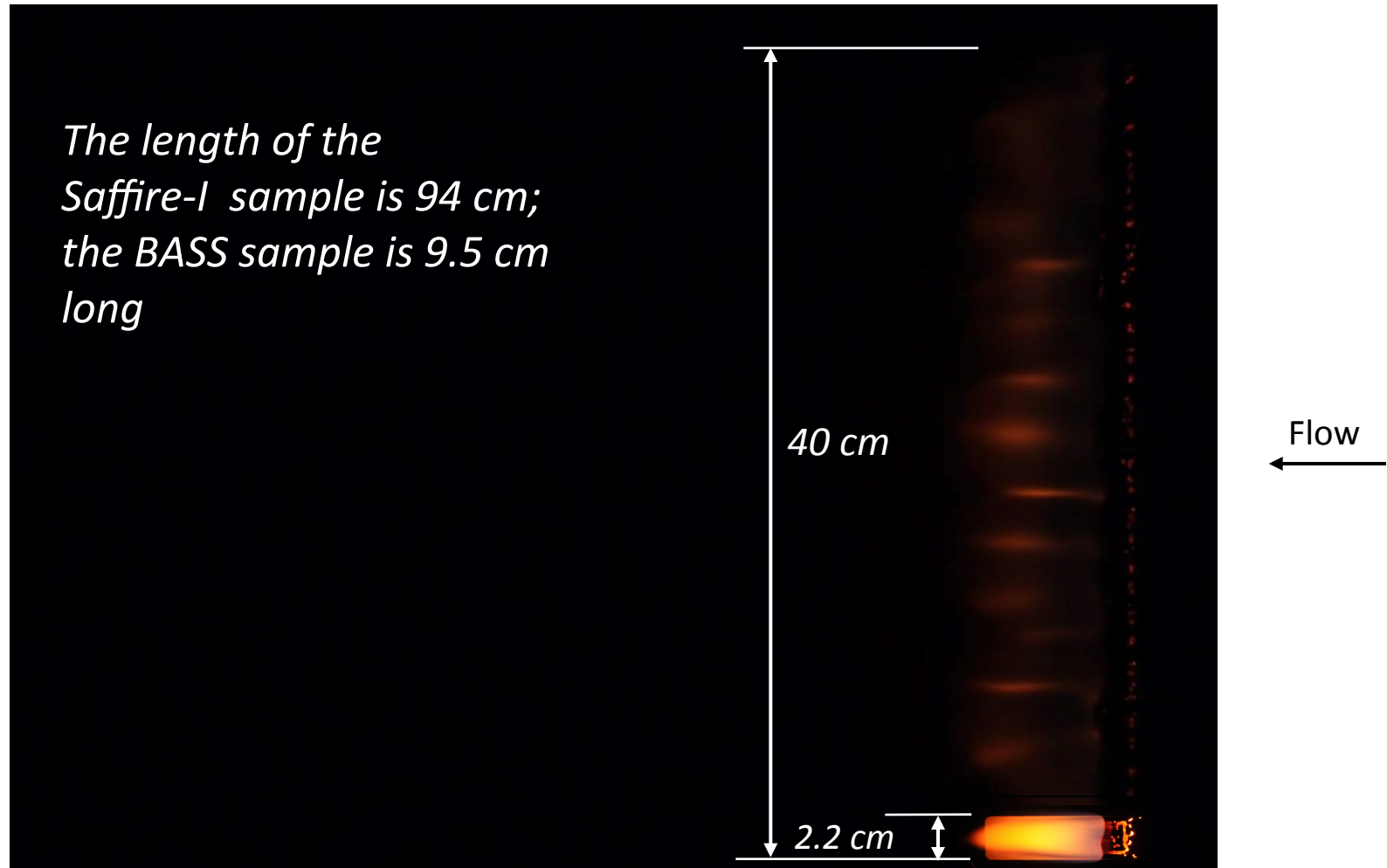
Saffire-I sample material at the beginning of the concurrent (upstream) burn.
Thermocouple wires are sewn into the sample material with thermocouple beads at various heights in the center of the sample.

Saffire-I Operations - *Concurrent Flow Igniter*



Video of the first 30 seconds of the Saffire I concurrent (upstream) burn. The burn continued similarly for seven minutes before the flow was turned off. The green LED is on for 1 second and off for two seconds (1 second out of three). Shorter times indicate missing downlinked frames.

Saffire-I Operations - *How big is the flame?*



Saffire-I flame compared to a flame from the Burning and Suppression of Solids (BASS) experiment conducted in the Microgravity Science Glovebox . Camera exposures and gains are different between the two experiments.

Saffire-IV, V, and VI Overview

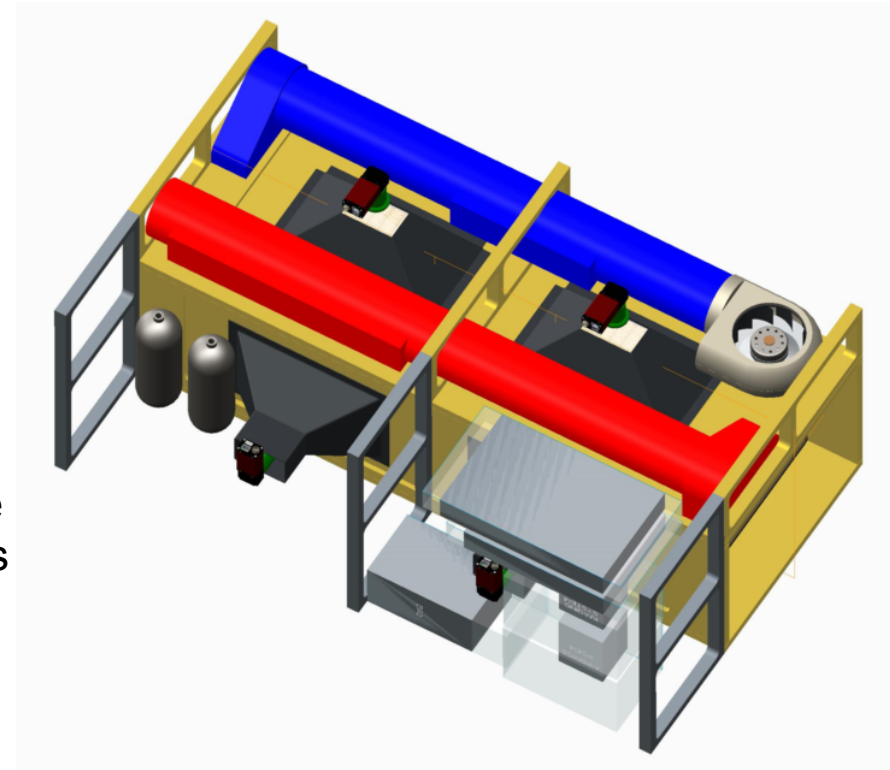


Needs:

- ◆ *Demonstrate spacecraft fire detection, monitoring, and cleanup technologies in a realistic fire scenario*
- ◆ *Characterize fire growth in high O₂/low pressure atmospheres*
- ◆ *Provide data to validate models of realistic spacecraft fire scenarios*

Objectives:

- *Saffire-IV:* Assess flame spread of large-scale microgravity fire (spread rate, mass consumption, heat release) in exploration atm
 - *Saffire-V:* Evaluate fire behavior on realistic geometries
 - *Saffire-VI:* Assess existing material configuration control guidelines
- All flights will demonstrate fire detection, monitoring, and cleanup technology



Conceptual design of Saffire-IV-VI experiment module. Dimensions are approximately 53- by 90- by 133-cm. additions from previous Saffire include side view of sample card and oxygen addition.

Saffire IV - VI Hardware Concept



◆ Concept consists of three distinct hardware locations

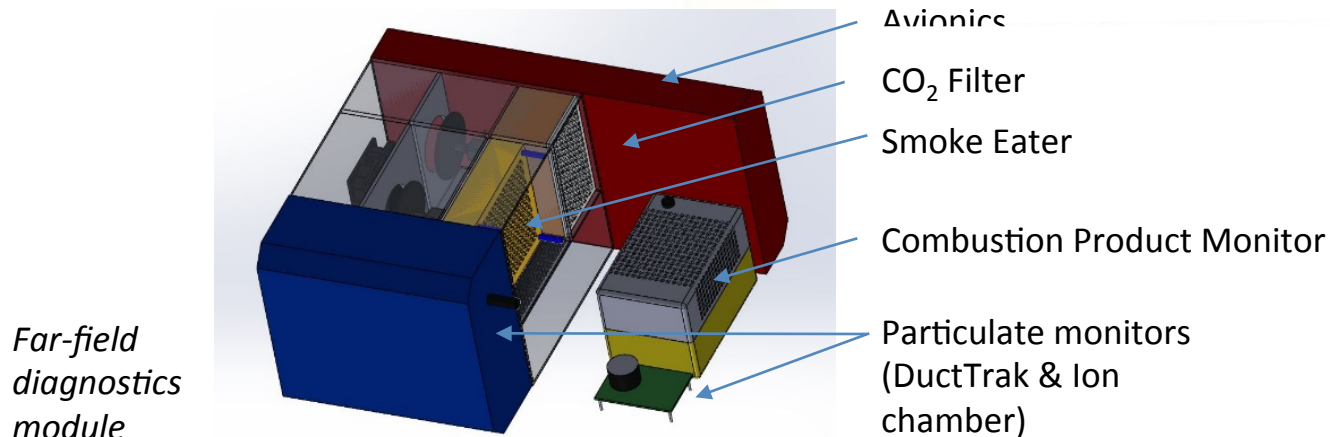
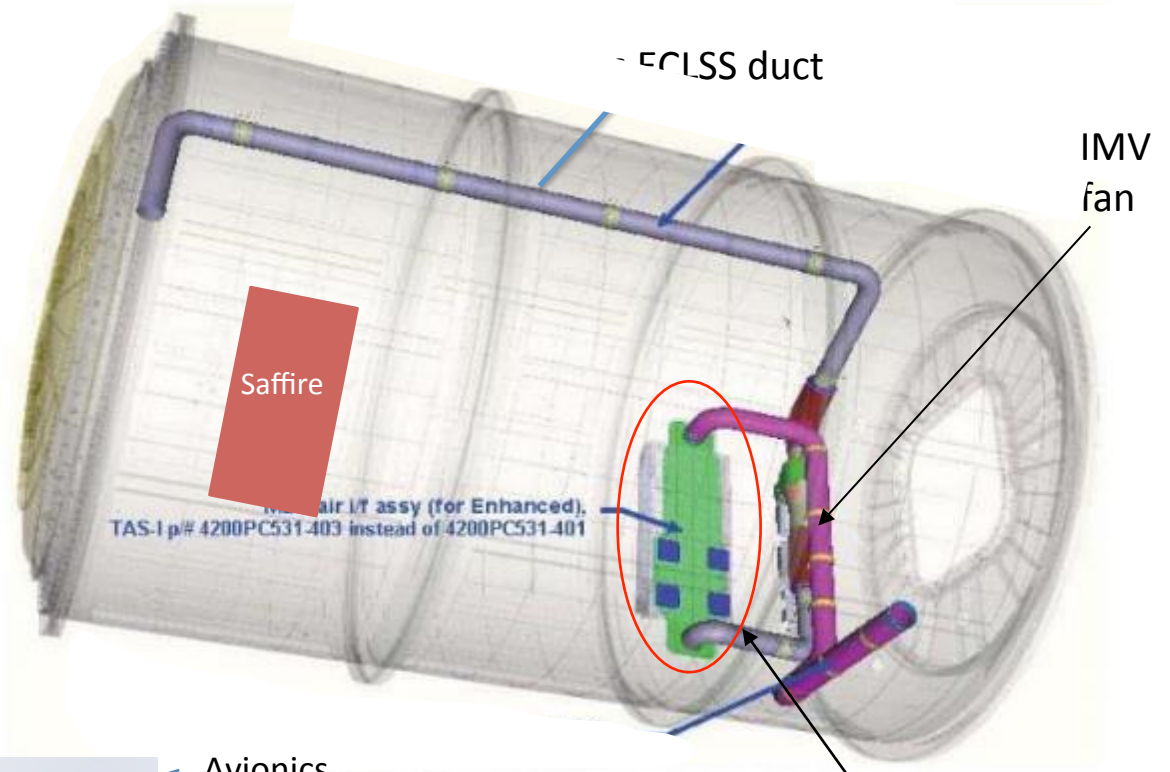
- Saffire flow unit
- FarA field diagnostic
- Distributed sensors

◆ Far-field diagnostic module

- Combustion product monitor
- CO and CO₂ sensors
- Post-fire cleanup module

◆ Distributed sensor network

- Temperature
- CO₂



Summary



- ◆ Fire Safety gaps are being addressed through ground and flight-based demonstrations
 - SaffireA I, II, and III are addressing material flammability gaps
 - SaffireA IV, V, and VI will address detection, monitoring and clean-up demonstrations
 - Technologies are being simultaneously developed for ISS and Orion
- ◆ Fire Safety SMT participates in definition of the demonstrations and evaluation of results

Overall SMT Next Steps



- **Use of SMT performance measures, roadmaps, and demonstration plans to drive:**
 - ISS (and ISS re-supply) technology demonstration planning and prioritization
 - Specific Proving Ground objectives
- **Ongoing refinement of roadmaps as specific Exploration mission architectures evolve**
- **Coordination through International SMT's to potentially incorporate partner contributions**
- **Development of standards (e.g. performance, common interfaces) to support interoperability between various commercial and international partner systems and components**
- **Continued integration across programs and projects/funding sources (ISS, AES, STMD) to advocate for funding of priorities, collaborate, and track through budget process**
 - e.g. ECLSS oxygen recovery is combination of STMD-sponsored early development followed by AES-sponsored flight hardware development, and ISS-sponsored flight demonstration & integration



Questions?