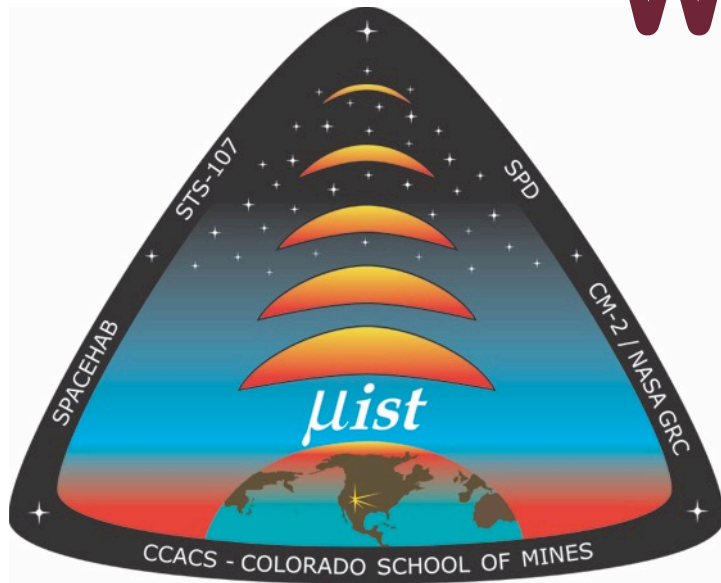


Fighting Fires in Space with Water Mist



September 21, 2016
Vienna, Austria



Angel
Abbud-Madrid

ADA
Technologies, Inc.

Thierry
Carriere

Apollo 1

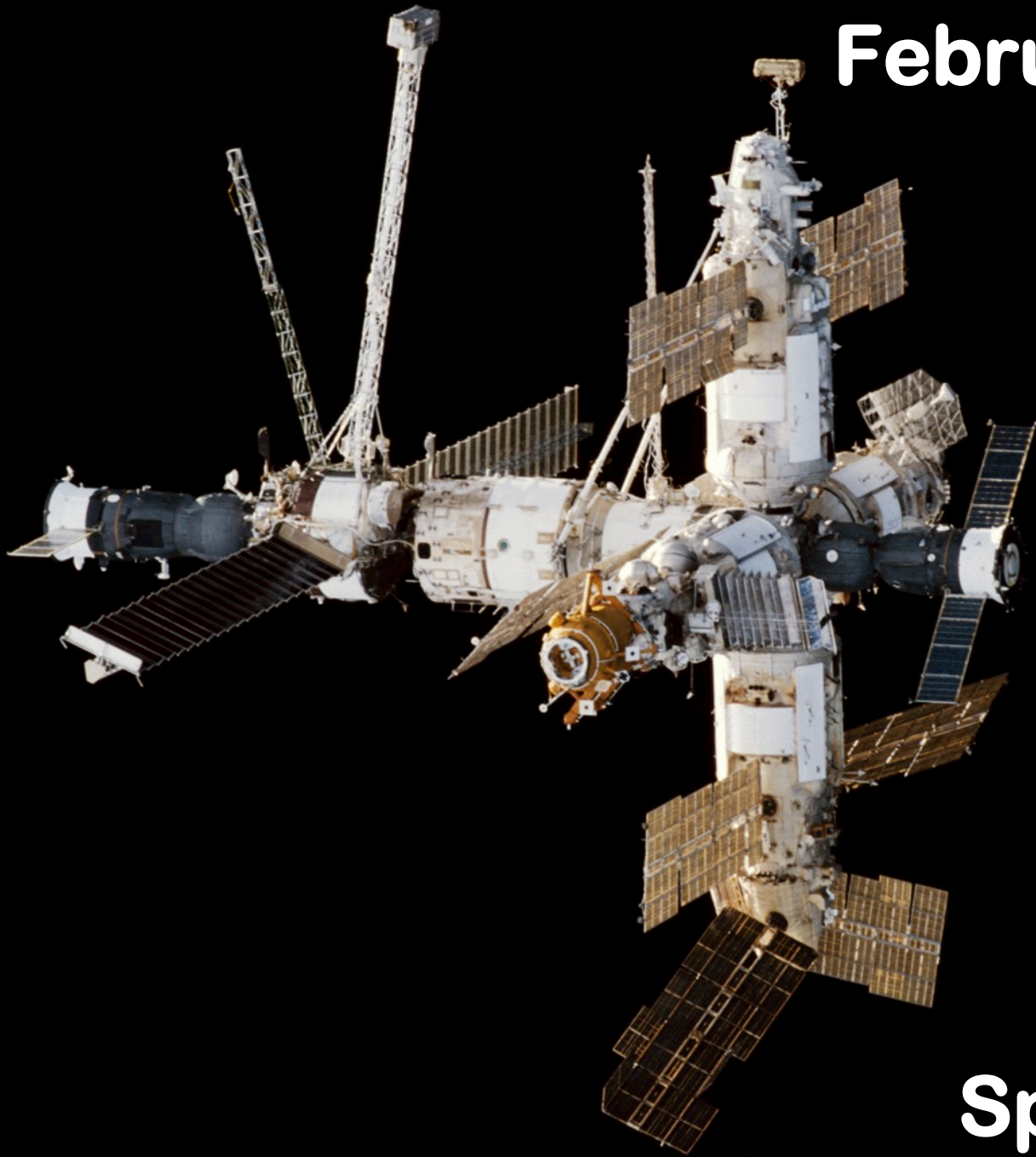
January 27, 1967



Lessons learned:

- * Switch from 100% O₂ to air**
- * Materials flammability**

February 27, 1997

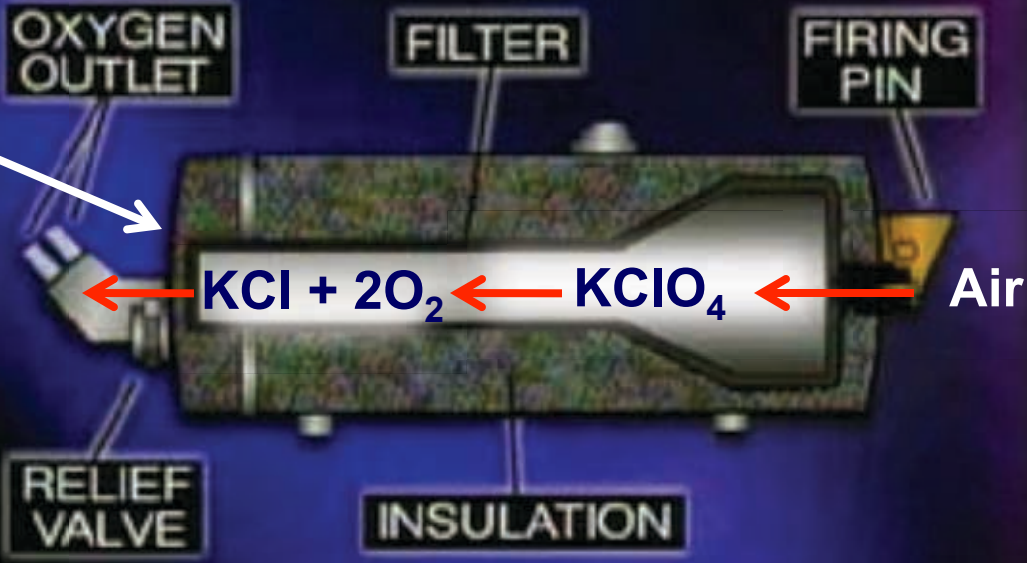


MIR
Space Station

Oxygen candle



OXYGEN GENERATOR





**Jerry Linenger
(US astronaut)**

Fire suppression in spacecraft



Halon
($\text{CF}_3 \text{ Br}$)

Chemical

Carbon
Dioxide
(CO_2)



Physical



Objectives for Alternative System

- ✓ **Per unit mass effectiveness**
- ✓ **Non-toxic and non-corrosive**
- ✓ **No need for masks and oxygen tank**
- ✓ **Cooling of flame and surroundings**
- ✓ **Ease of clean-up**
- ✓ **No need for de-orbiting**
- ✓ **Refilling of extinguisher**

Motivation (1997)



**CF₃Br
(Halon)**

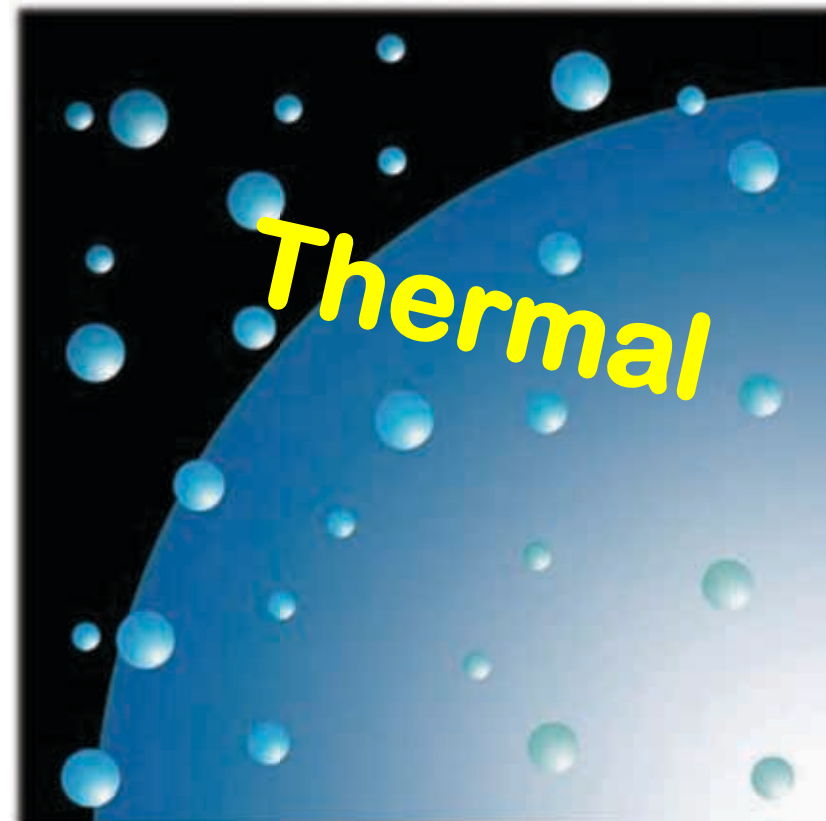


H₂O

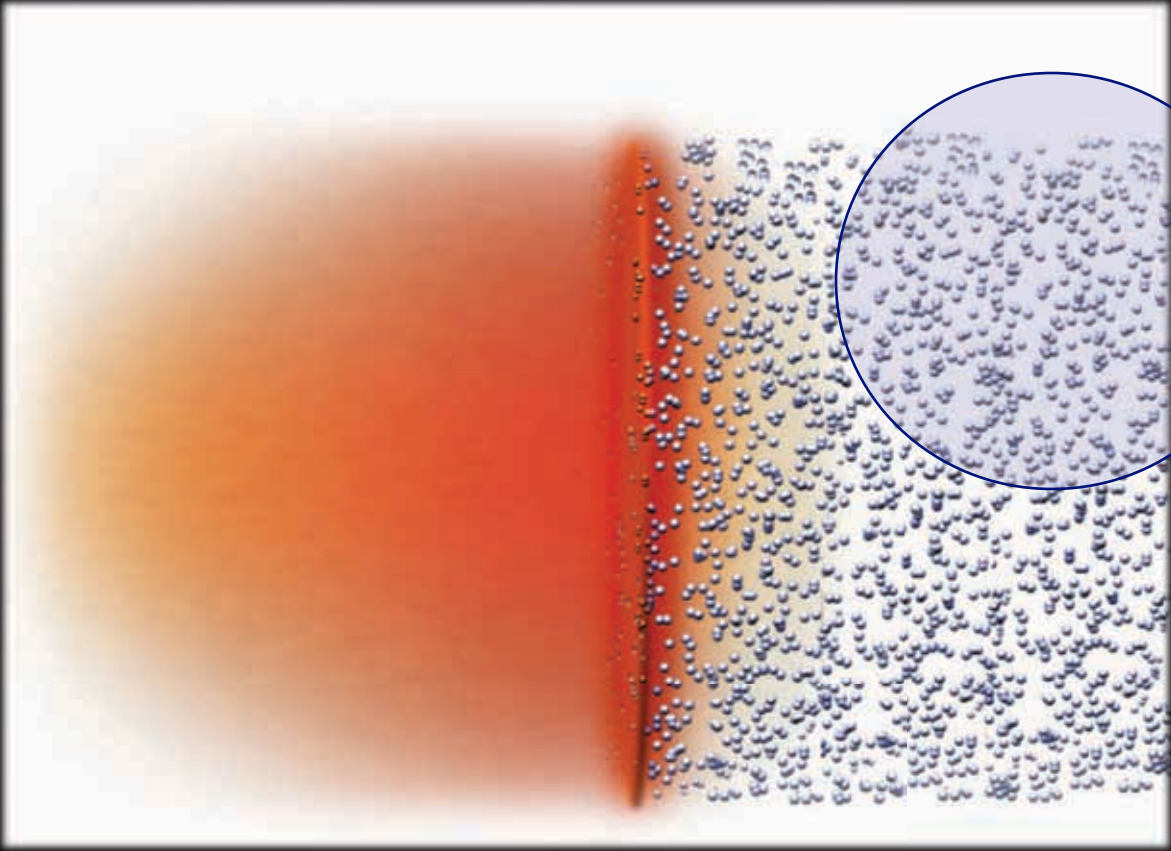


**Montreal
Protocol
(1994)**

Water mist



Determine effect of:

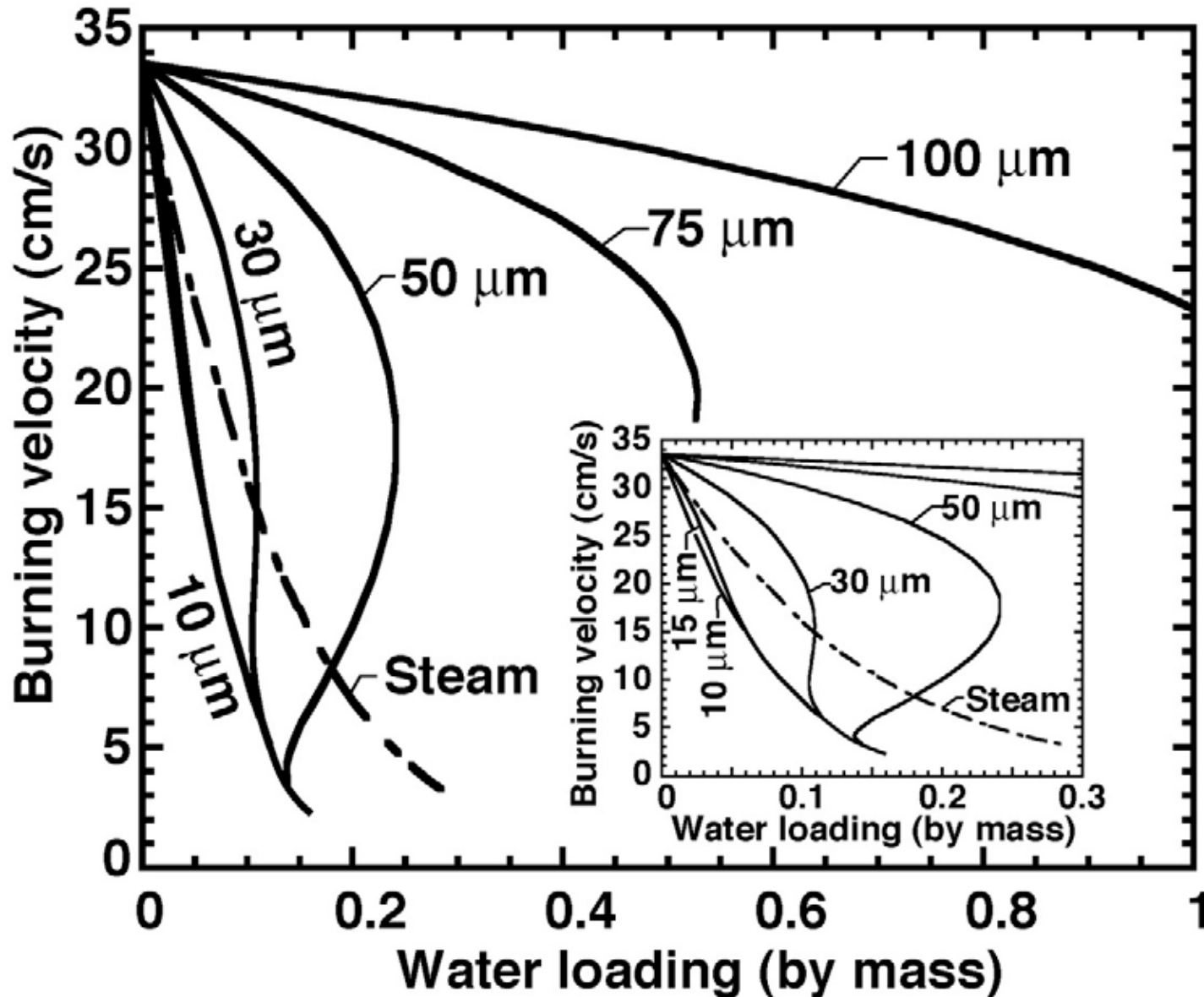


Water amount



Droplet Size

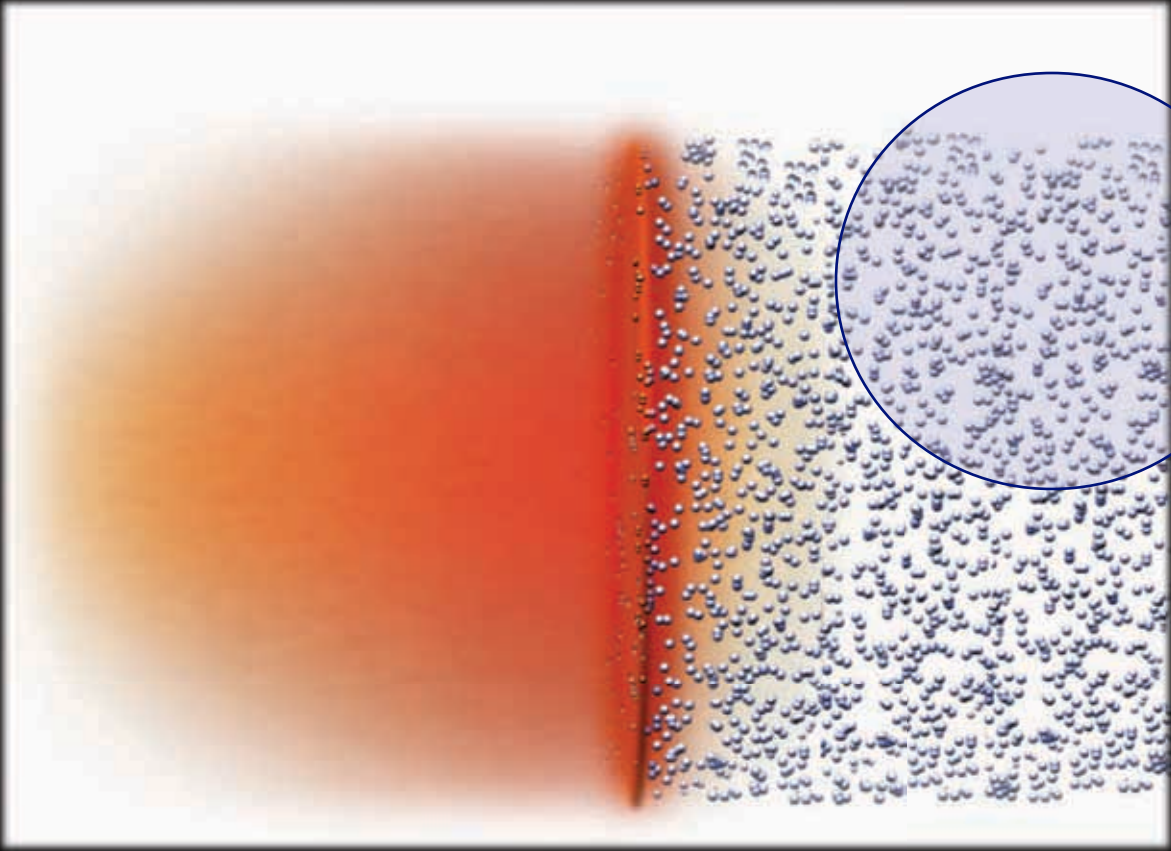
Numerical Model Results (CH₄-air, $\phi=1$, 1 atm)



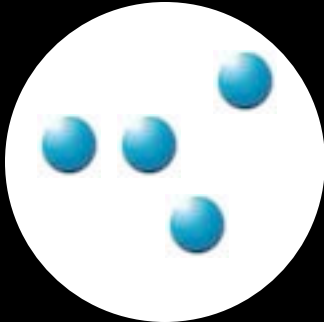
GROUND TESTING



Determine effect of:



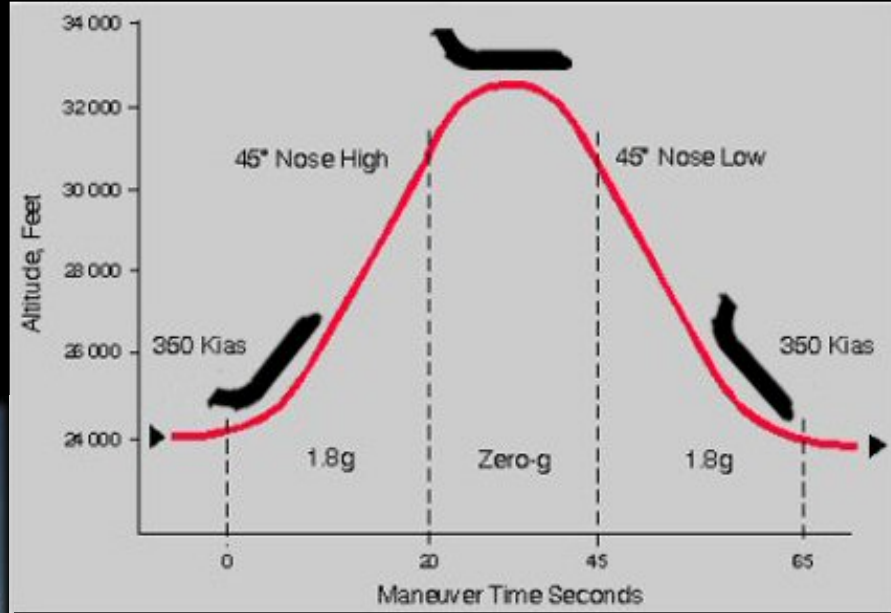
Water amount



Droplet Size

~~Gravity~~

Free fall (Weightlessness)

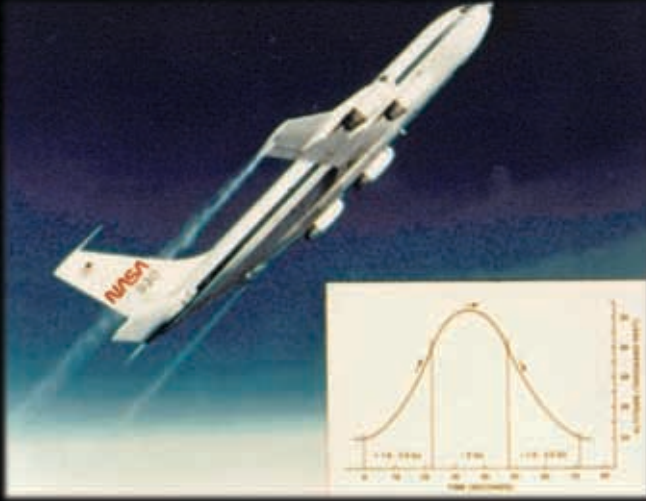


Fall height = 3000 m

Time ≈ 25 sec



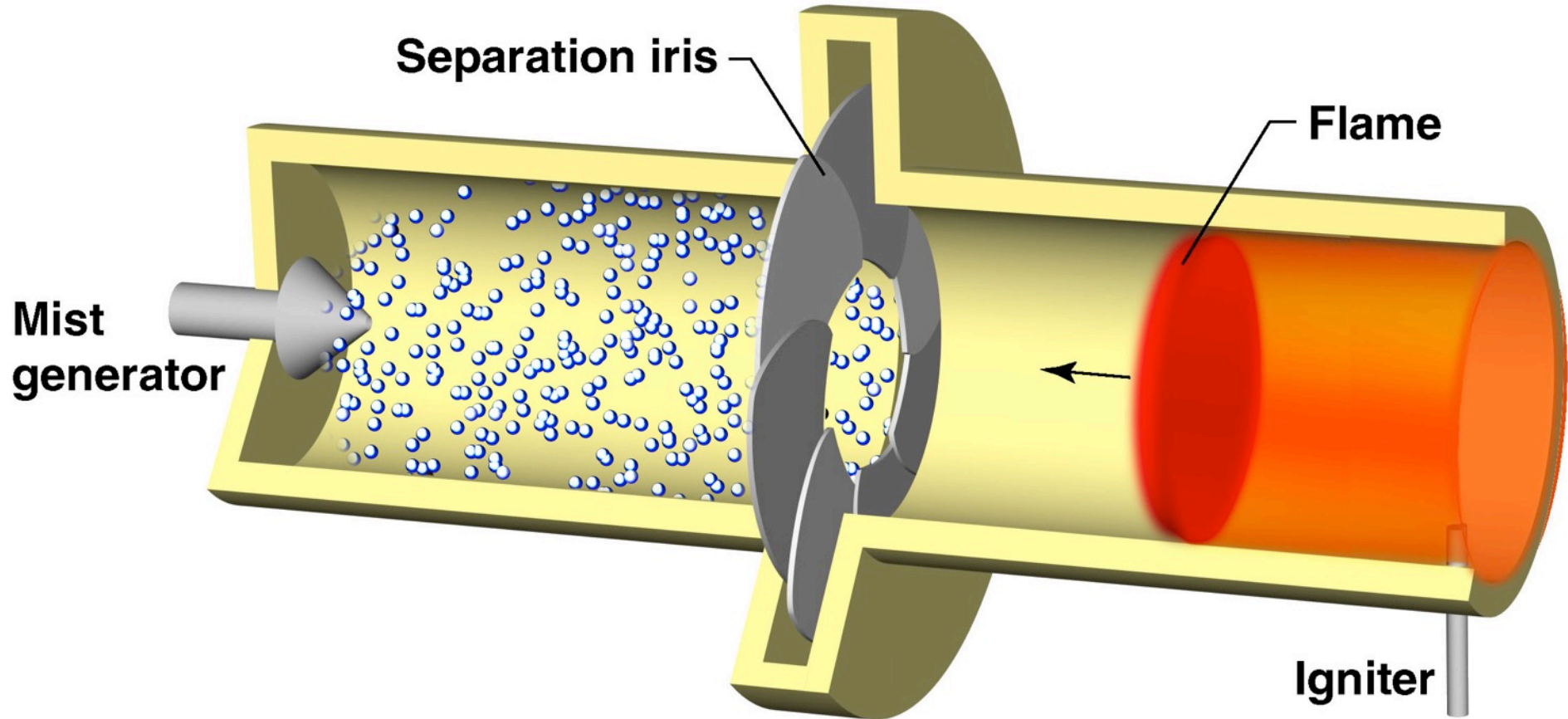
Free fall tests (no gravity effects)



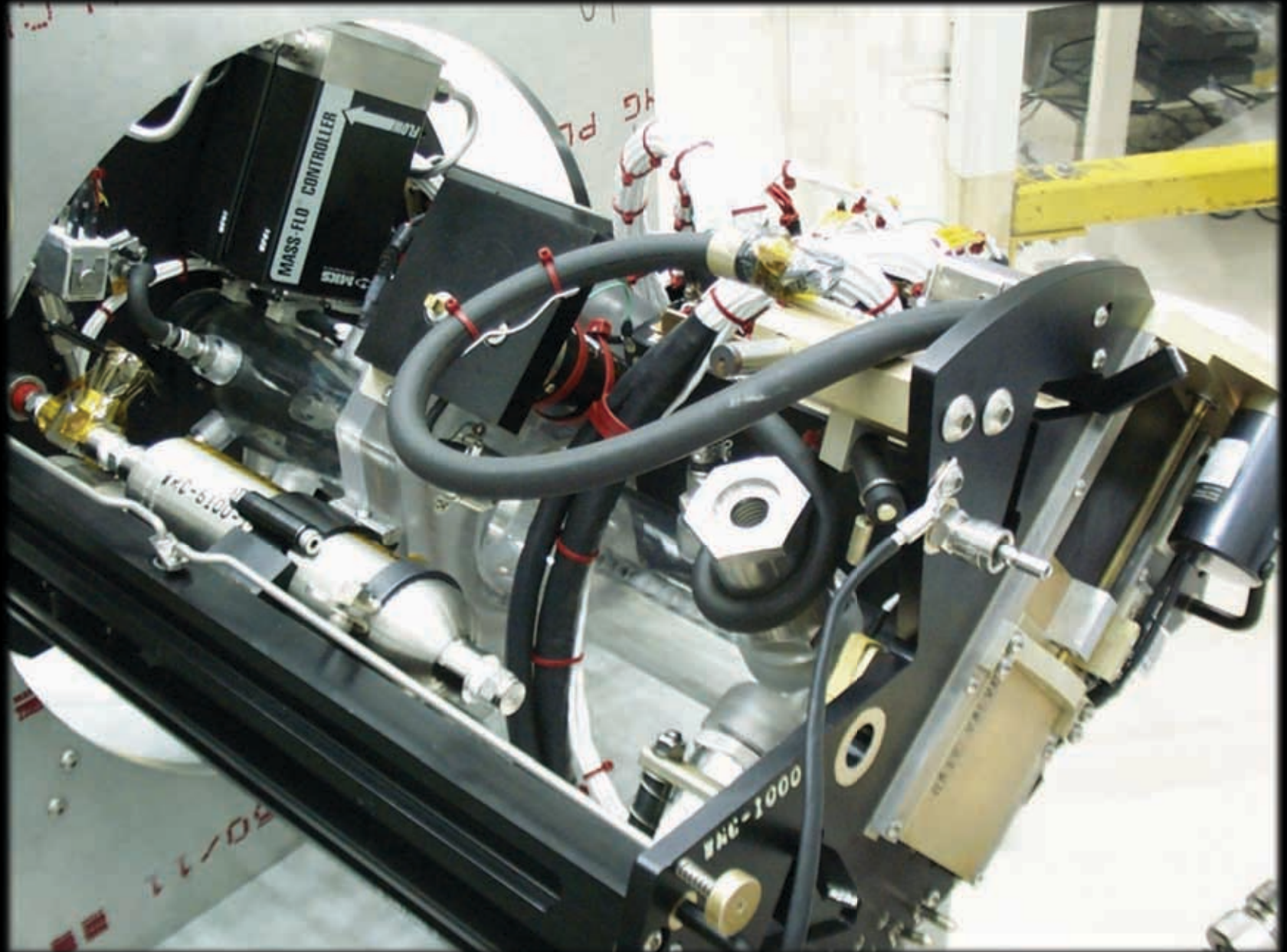
Free fall around Earth (Space Shuttle)



Flight Experiment



MIST apparatus

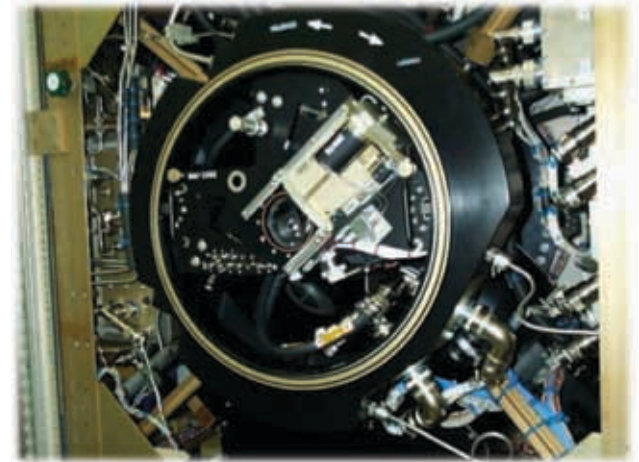


Hardware Integration



Mist apparatus

***Mist inside
combustion
vessel***



**Combustion vessel
inside rack**

**Rack inside
SPACEHAB module**

SPACEHAB inside Shuttle



Crew Training



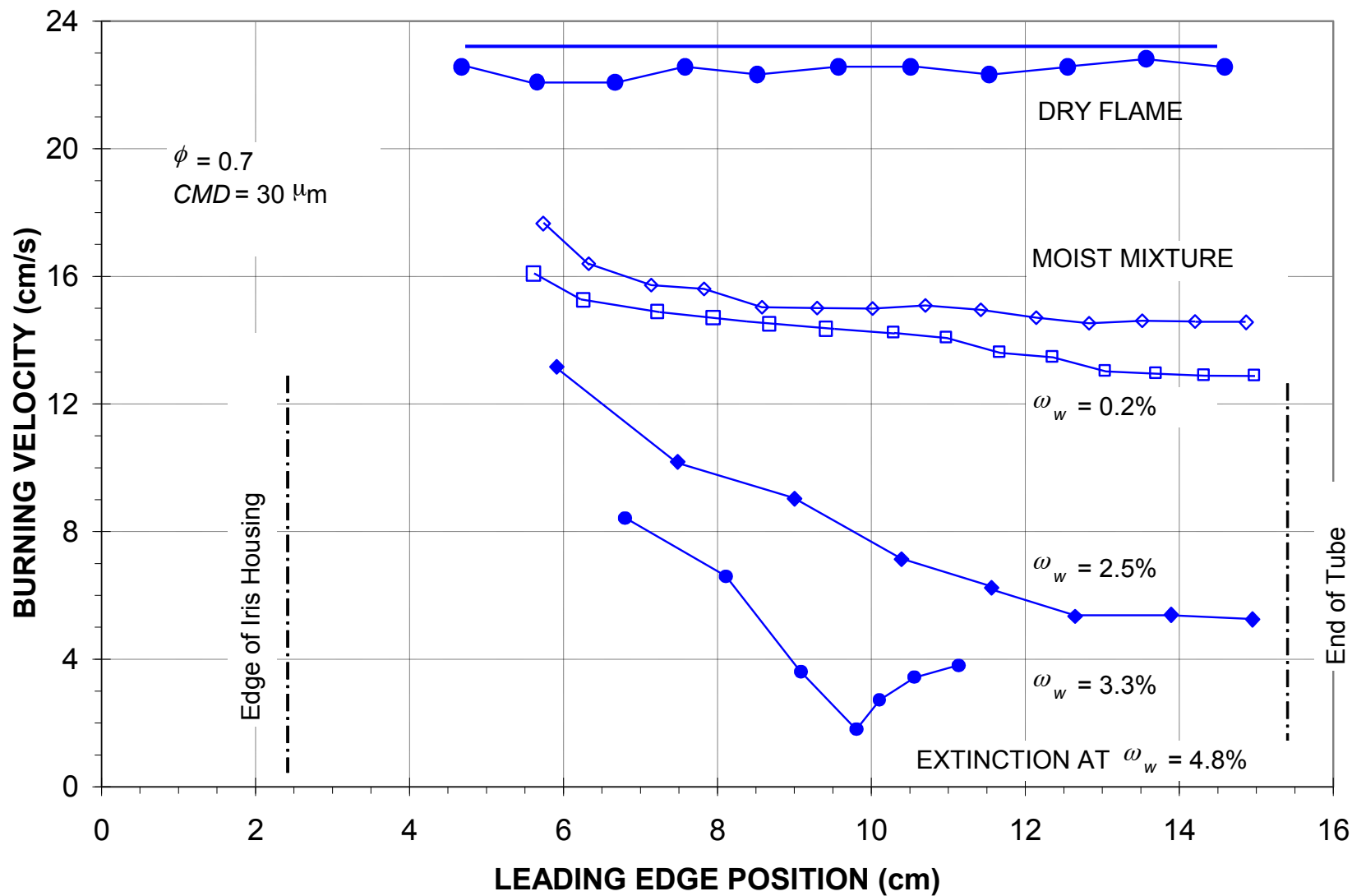
STS-107 Shuttle Mission (January 16, 2003)



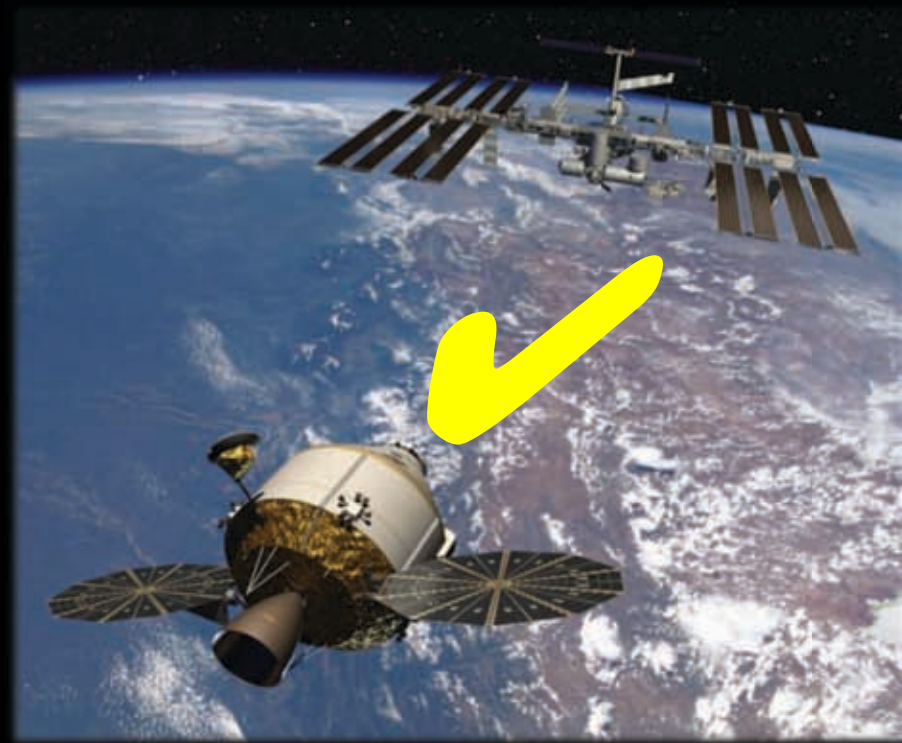
Mist in Orbit



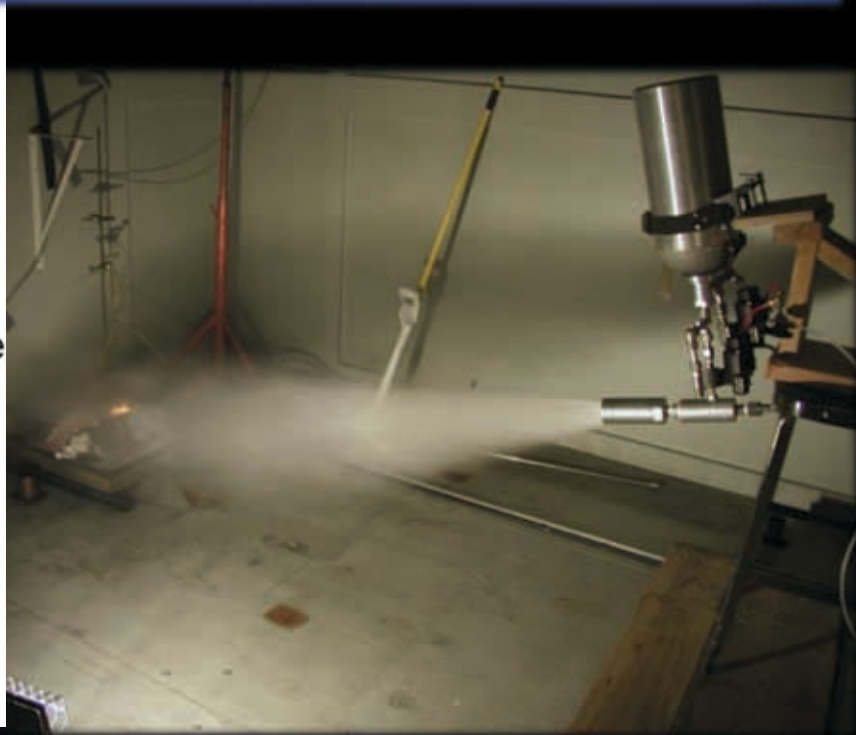
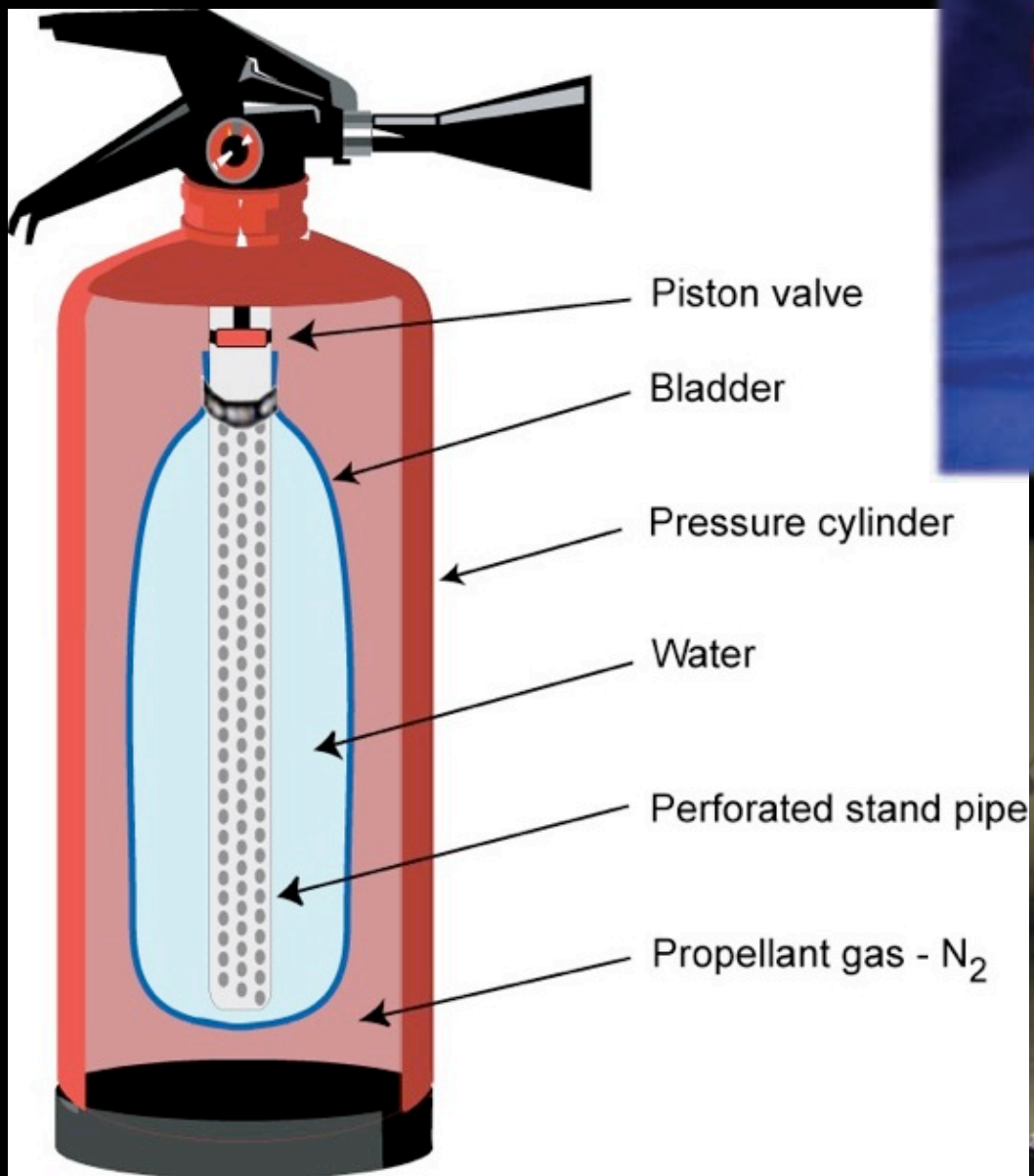
Results: C_3H_8 -air flame (Droplet CMD = 30 μm)



2003 ...



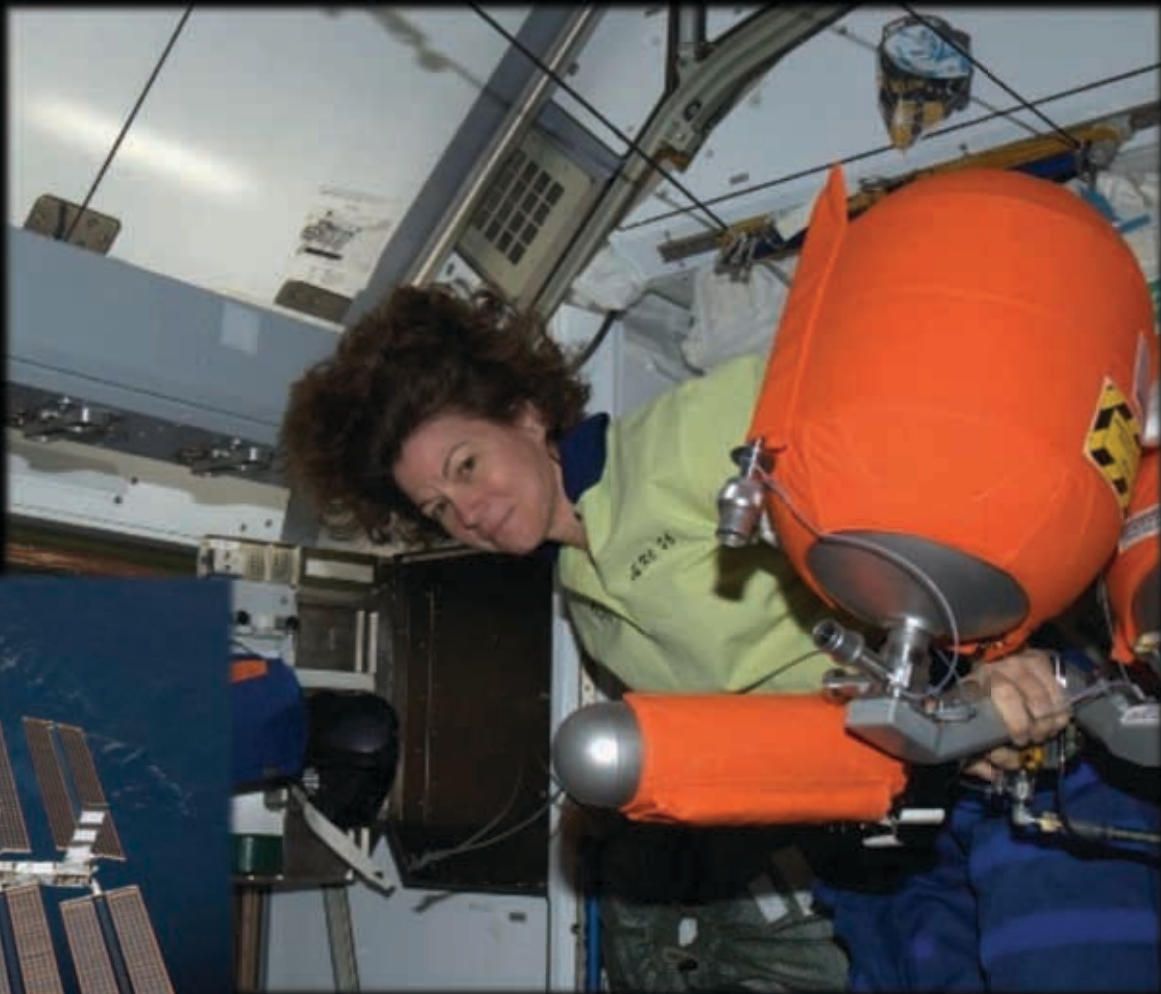
Portable Fire Extinguisher



Microgravity tests



2011 ...



ISS life extension: 2020 → 2028
Replacement of CO₂ extinguishers

ISS Water Mist Portable Fire Extinguisher project



Water Mist Portable Fire Extinguisher (WM PFE)

Titanium bellows tank



FIRE SCENARIOS ONBOARD THE ISS



Open Cabin

Oxygen candle



Elevated O₂ module



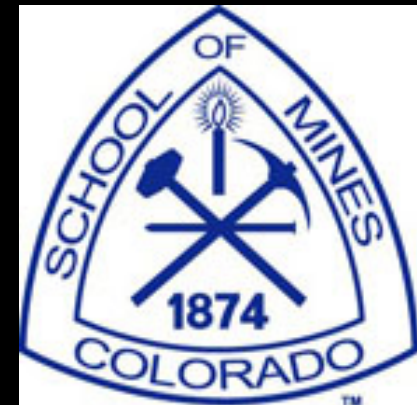
Li-ion batteries



Racks

ISS Fire Scenarios tests

1) Open Cabin Fire (PMMA sheets, 55 kW)



ISS Fire Scenarios tests



White
Sands
Testing
Facility

2) Elevated Oxygen Fire (PMMA crib, 30% O₂, 85 kPa)



ISS Fire Scenarios tests



White
Sands
Testing
Facility

3) Li-ion Battery Fire (2 units, PMMA crib)

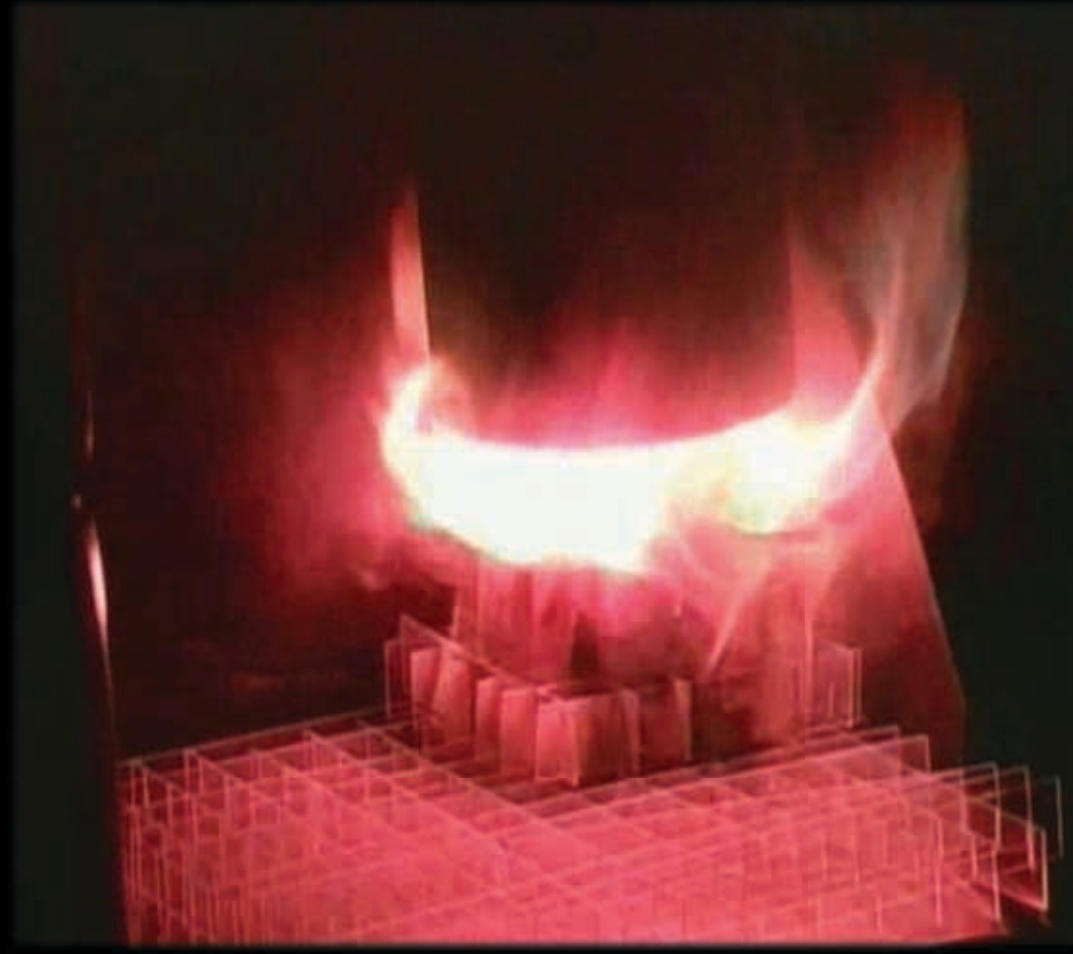


ISS Fire Scenarios tests

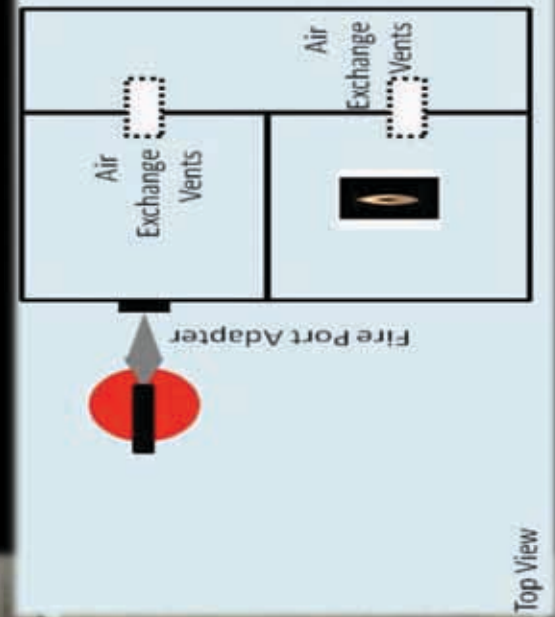


White
Sands
Testing
Facility

4) Oxygen Candle Fire



ISS Fire Scenarios tests

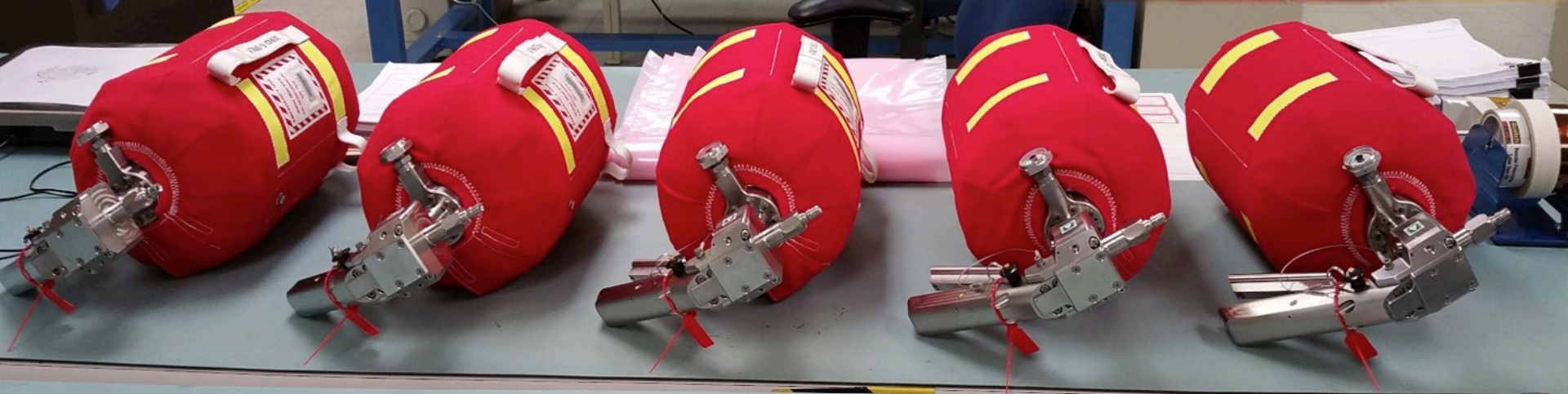


5) Rack Fire



**Final test with
prototype PFE**

Flight PFE units (Total: 9)



First 2 PFEs delivery (Cygnus OA-4 mission)



First PFEs delivery (Atlas V launch, 12/06/15)



Cygnus arrival to ISS (12/08/15)



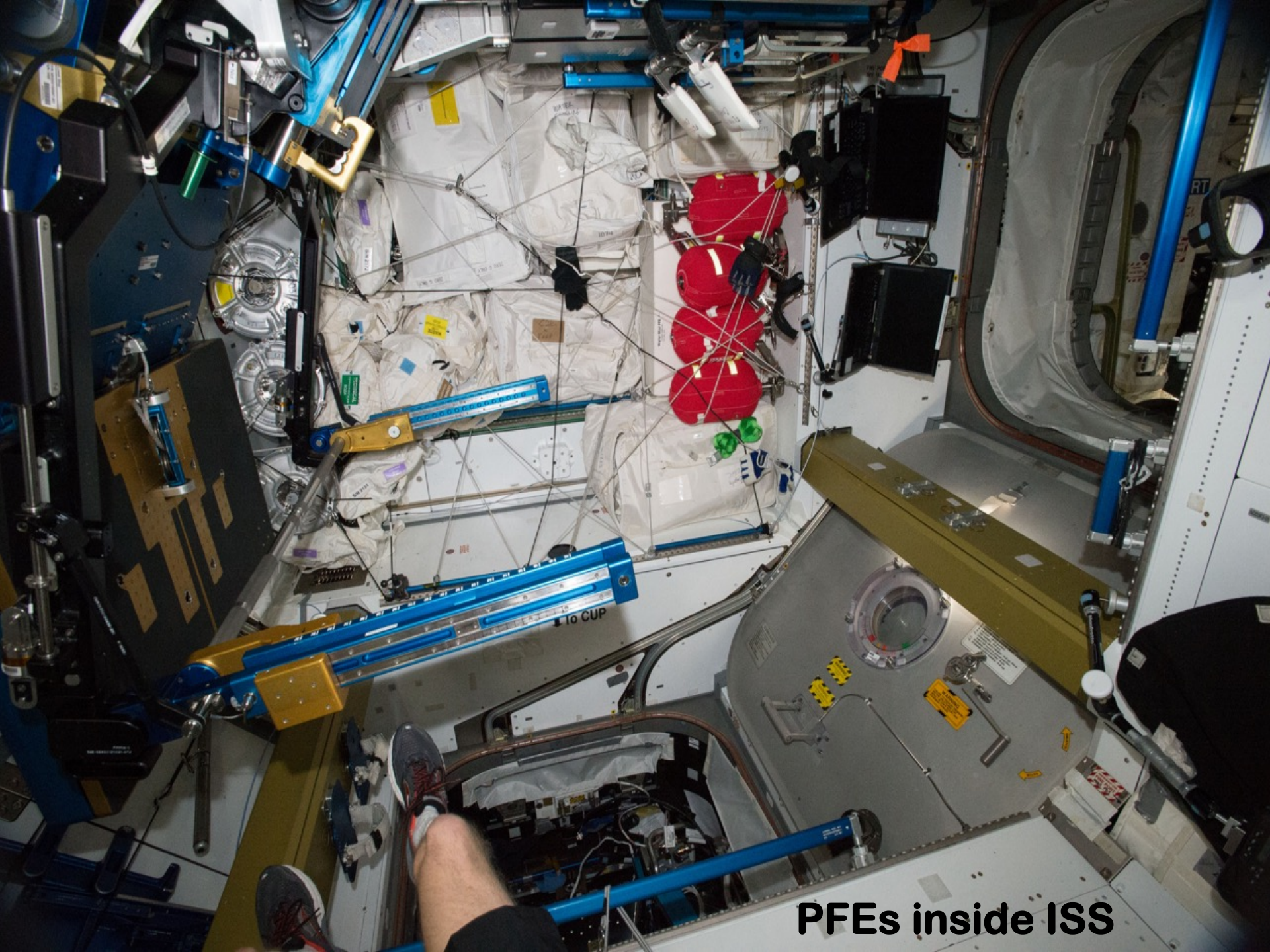


March 23, 2016
(4 units)



April 8, 2016
(2 units)



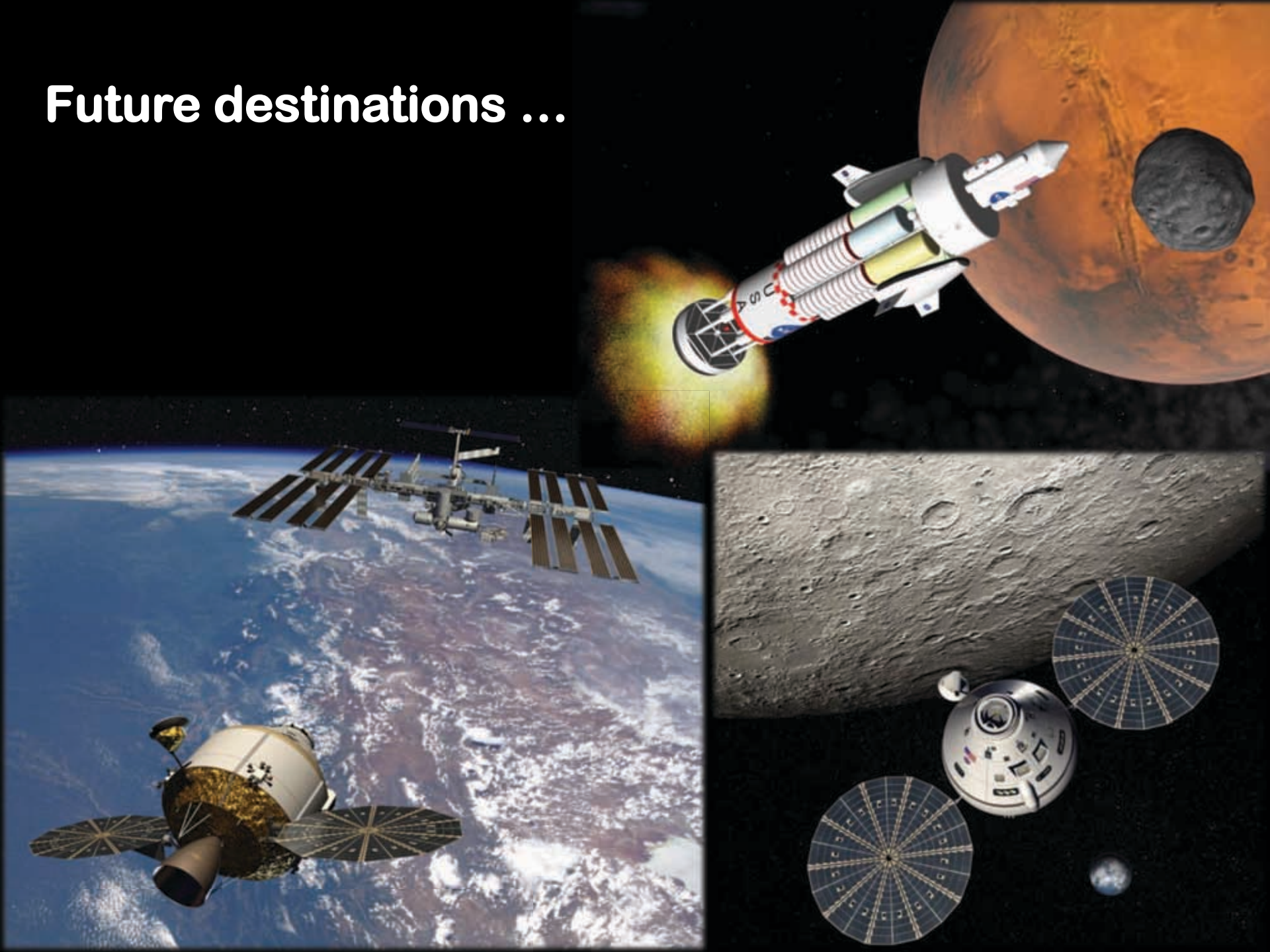


PFEs inside ISS



**Coming up ...
October, 2016
(Last unit)**

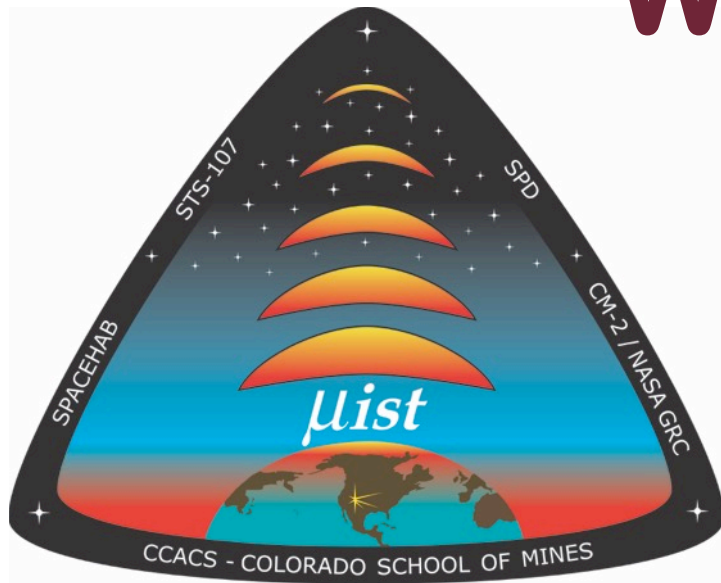
Future destinations ...



The Mist crew ... In memoriam



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