Flammability Limits at Reduced-g Experiment (FLARE)
Task Group 5

Fundamental Research on International Standard of Fire Safety in Space on the ISS/JEM

Presenters

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WSTF Team

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Task Group 5

◎Harold D. Beeson (NASA WSTF)	Comparison of the result of material safety evaluation between an existing NASA-STD-6001 Test 1 test method and a new test method of safety in space; and discussion with JAXA and ESA on coorelation and appropriateness of the test method
David Hirsch (NASA WSTF)	
Susana Harper, Jon Tylka, Alfredo Juarez, Brenton Woods (NASA WSTF)	
Hiroyuki SHIMAMURA (Human Space Safety and Mission Assurance Office, Human Spaceflight Mission Directorate, JAXA)	Study of fire safety standard and discussion on appropriateness of the test method with NASA and ESA from Japan's standpoint
Osamu FUJITA (Hokkaido Univ.)	
Thomas Rohr (ESA ESTEC)	Study of fire safety standard and discussion on compatibility of the test method with NASA and ESA from European standpoint
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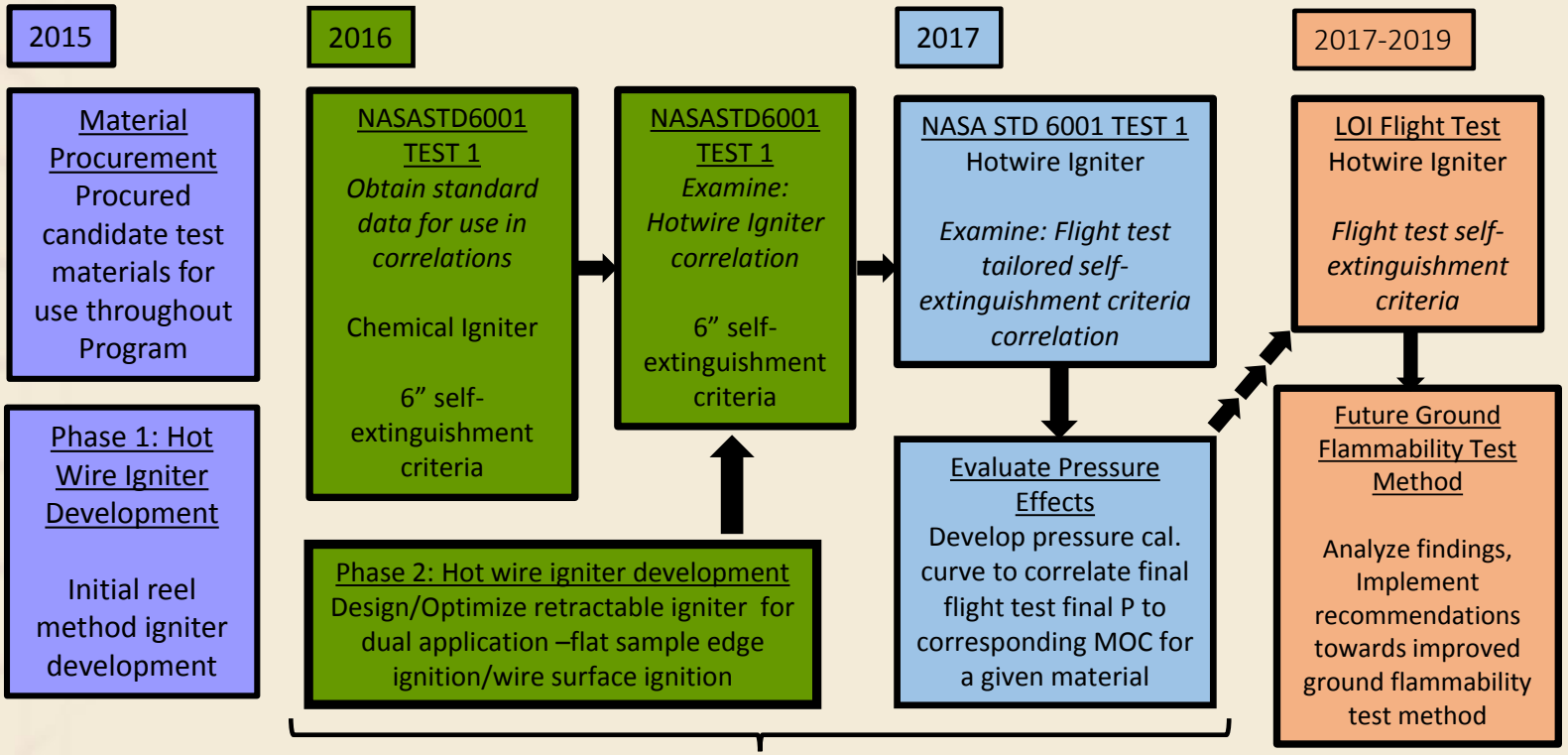
Task Group Goals/ Timeline

- Correlation Pathway to compare NASA-STD-6001 Data to flight LOI data



Materials Definition/Procurement

Test Material Definition/Procurement

- All Materials ordered and at WSTF
  - LDPE pellets and ETFE Tefzel 750 pellets and Nomex shipped fall 2015
  - Awaiting second drop of funds to ship remaining sheet materials (HDPE, LDPE, PMMA)
- Wire Configuration Materials
  - ETFE Tefzel 750 Pellets
  - LDPE Dupont Series 20 Pellets
- Sheet Materials (tried to purchase materials in various thicknesses)
  - HDPE Tivar 1000 (HD) preferred due to high purity (not radiation cross-linked)
    - 1.6 (2.29) mm, 3.175mm, 4.749mm, 6.35mm
  - LDPE by ASTM D4976
    - 1.6mm,3.175mm
  - Cast PMMA (reduce dripping)
    - 0.8 mm, 2.99mm, 5.99 mm
  - Nomex HT090-40 (AKA HT90-40)

Questions

- What is the maximum material thickness currently being considered?
- Are there any finalist materials that are being focused on?

Phase 2: Hot wire igniter development

Design/Optimize retractable igniter for dual application

Sheet sample edge ignition
Rod surface ignition

Hot Wire Design - Background

- Multiple variables changed during iterative steps
- All Tests performed on various thickness of PMMA as a reference material
- Test conditions
  - Previously reported PMMA MOC used as initial concentration to qualify design
    - Chosen to examine ignition @ propagation threshold
  - All design qualification tests performed @ 101.3 kPa (14.7 psia) and ambient temperature

Design Assumptions

- A gap will be left on one edge of holder for retractable igniter to be moved into position (edge ignition)
- Rod configuration will run full length (surface ignition)
- Igniter design limited by sample configuration (20 mm max)

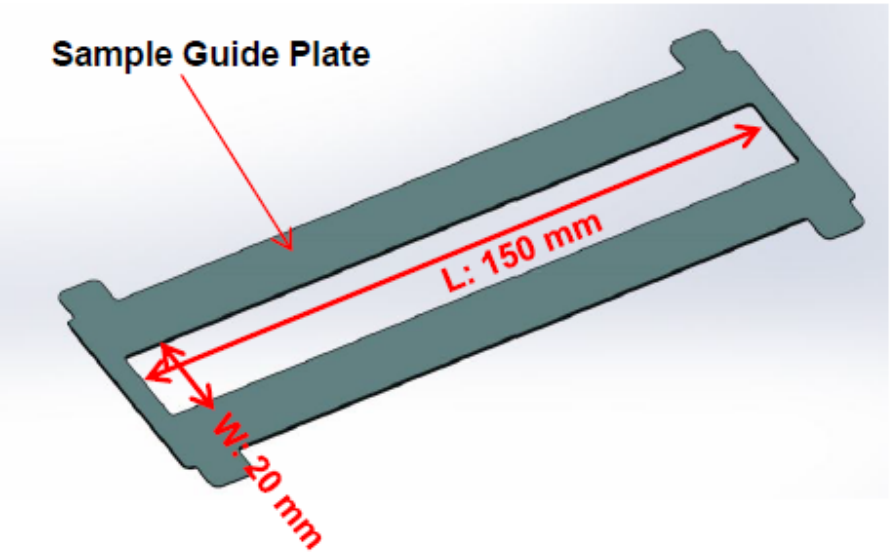


Figure 5. Schematic of the sample holder for the narrow sample for experiments #3 and #4.
Each fuel sample is sandwiched between two sample guide plates (top side and bottom side) so that the sample keeps its flatness and location in the flow duct. This sample geometry will be used for both experiment #3 (PMMA sheet) and #4 (Filter paper sheet).

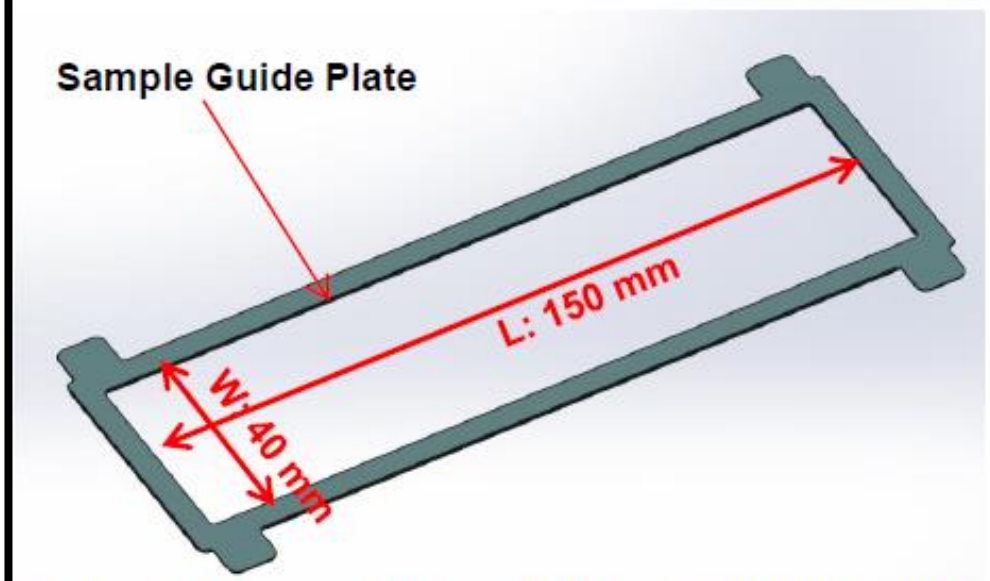


Figure 6. Schematic of the sample holder for the wide sample.
One test sample is sandwiched between two sample guide plates (top side and bottom side) so that the sample keeps its flatness and location in the flow duct. This type of sample is only employed in the experiment #4 (Filter paper sheet).

Provides Sufficient Heat Flux

- Coil Diameter
- Profile
- Length
- Wire Material
- Wire Gauge
- Number of Coils

Doesn't Break with Heavy Fuel Load

- Number of Coils
- Diameter
- Profile

Effective over wide O2 Range

- Wire Gauge
- Wire Material
- Profile
- Amperage Profile
- Flow Ports

Life Span

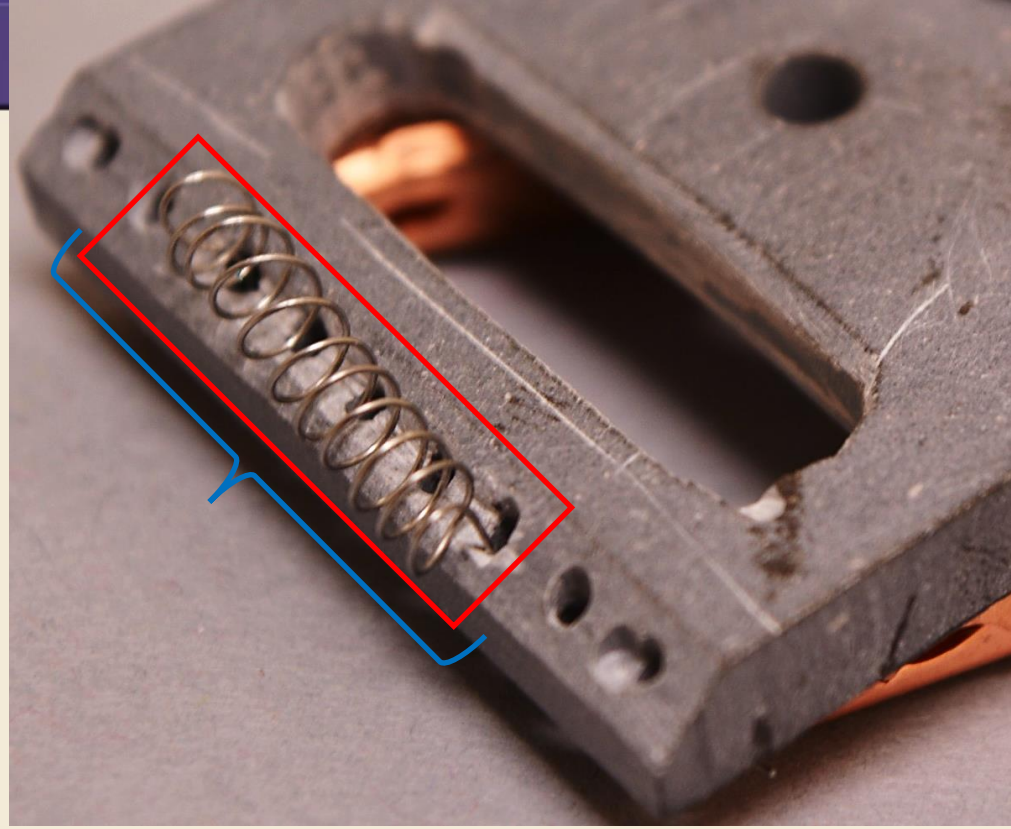
- Sample Type
- Wire Gauge
- Wire Material
- Amperage Profile
- Retractable

Does not obstruct Flowstream

- Flow Ports
- Retractable
- (injection, cantilever?)

Prevent Sagging

- Channeled/Chamfered Support
- Amperage Profile
- Wire Gauge



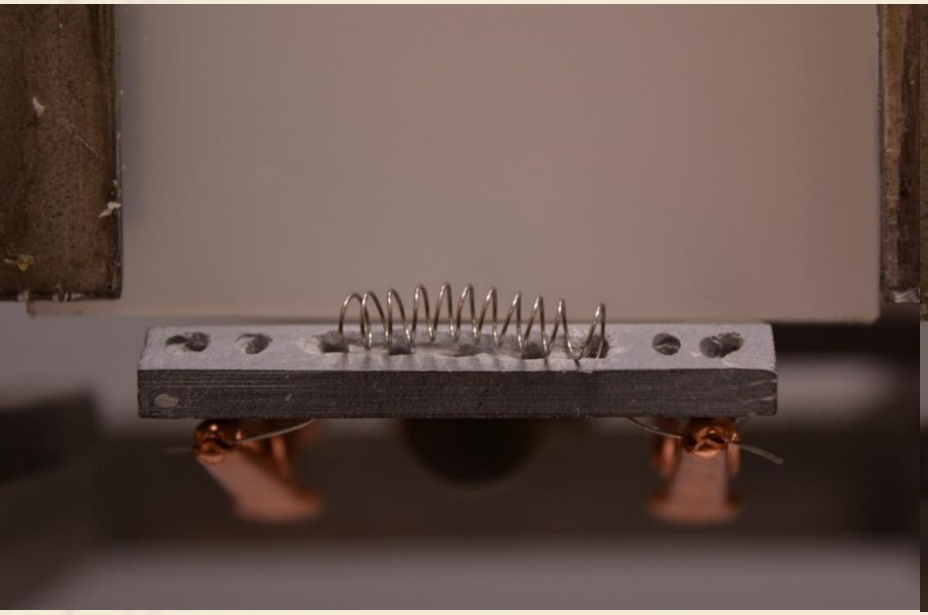
Sample/Igniter Contact

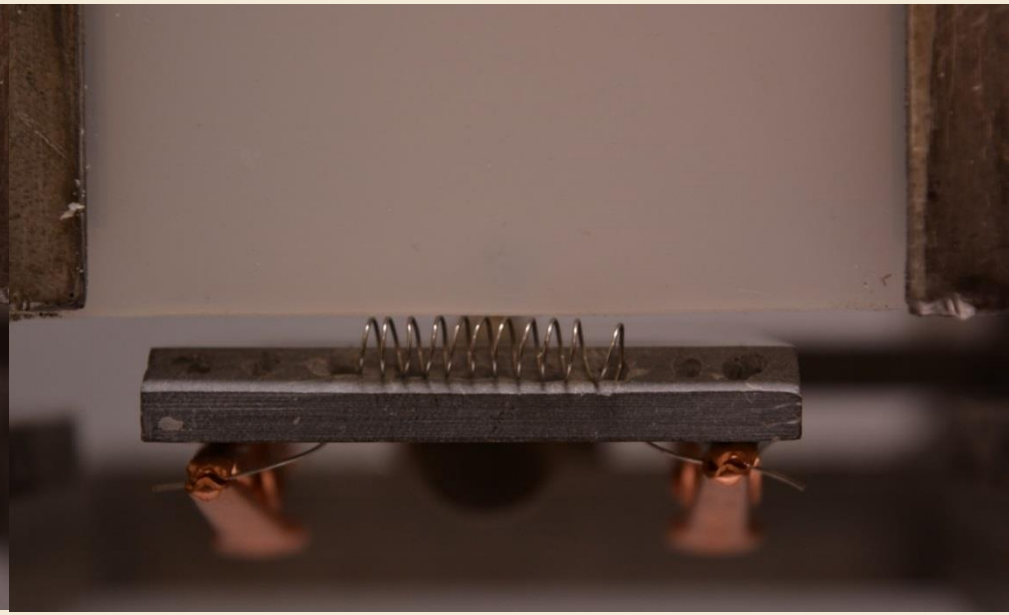
- Coil Bowed by tension
- Chamfered Support (edge/surface ignition)
- Wire Material
- Amperage Profile
- Retractable

Sample/Igniter Contact

Edge Ignition Sheet Sample Configuration

- Bowed igniter due to tension
- Igniter in contact with Sample

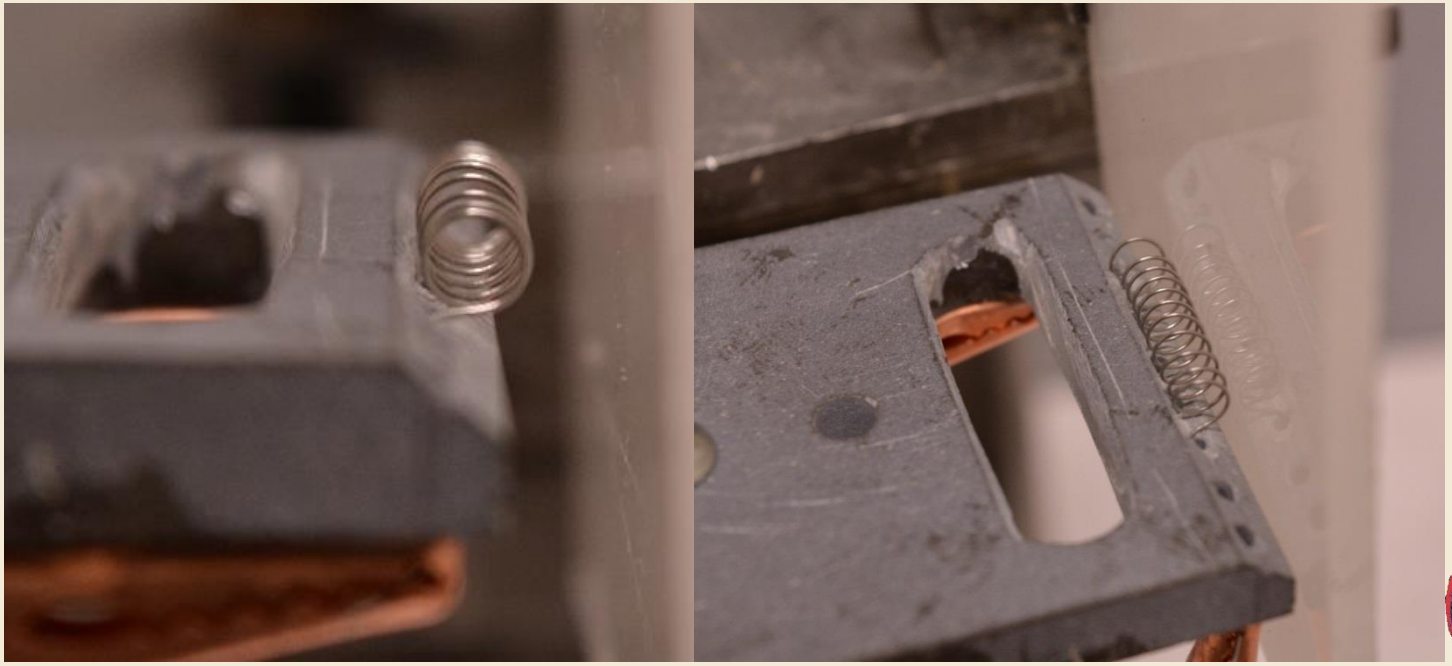




Sample/Igniter Contact

Surface Ignition Sample Configuration

- Bowed igniter due to tension
- Chamfered edge allows igniter to protrude beyond support
- For rod sample configuration



Recommended Igniter Design

Key Features	Experimental Range	Preferred
Hot wire profile	Helical, sinusoidal, linear	Helical coil
Length	20, 40 mm	20 mm (0.79 in.)
Number of coils	4-25	10 coils
Mandrel diameter	0.0625”-0.25”	0.125”
Carrier design	Unsupported, solid ceramic, channeled ceramic	Channeled ceramic
Igniter position	Horizontal, Chamfered	Chamfered
Amperage profile	Highly Variable; Maximum Power output – 120W (24V/5A)	(5A/5s)/(4.5A/25s)
Wire material	Nichrome, Kanthal KA-1	Kanthal KA-1
Wire gauge	18-29 ga	28 ga

Questions

- Is the system currently designed for a specific retraction method?
  - Will an injection or cantilever method work?
  - Are flight dimensions finalized?
- Will sample holder be conductive?
  - May create problems if contacts hotwire (20mm)
- Is there a prescribed pressure for sample/Igniter contact?

NASA STD 6001 Chemical Igniter/ Recommended Hotwire Correlation

Chemical/ Hotwire Igniter Comparison

Material	Nominal Thickness mm	Nominal Thickness inch	Material Tracking WSTF #	MOC Testing WSTF #	MOC per NASA-STD-6001 Test 1 Chemical (Seq A)	MOC per NASA-STD-6001 Test 1 Hot Wire (Seq B)
Tivar 1000 (HDPE)	1.6 (2.29)	0.063 (0.09)	15-46766	15-46775	18.00	18.0
Tivar 1000 (HDPE)	3.175	0.125	15-46767	15-46776	18.04	18.0
Tivar 1000 (HDPE)	4.749	0.187	15-46768	15-46777	In Test	In Test
Tivar 1000 (HDPE)	6.35	0.25	15-46769	15-46778	In Test	In Test
LDPE	1.6	0.06	15-46764	15-46773	18.03	18.03
LDPE	3.175	0.125	15-46765	15-46774	18.03	19.02
PMMA	0.8	0.03	15-46770	15-46779	MOC below Igniter Threshold	Pending
PMMA	2.99	0.118	15-46771	15-46780	MOC below Igniter Threshold	Pending
PMMA	5.99	0.236	15-46772	15-46781	MOC below Igniter Threshold	Pending

Observations

- Failure criteria consisted of NASA-STD-6001.B criteria
  - 6 in. burn length
  - Flame transfer by burning debris
  - MOC result is conservative
- Multiple failures were attributed to the flame transfer rather than burn length
  - Significant melt flow observed
  - Potential to impact microgravity testing
- Burn Length MOC (BLMOC) test performed
  - Removed K-10 Paper
  - Implemented quenching bath to limit impact of flaming debris on test sample