HEALTH & SAFETY LABORATORY

PRESLHY: Final Plan WP4 15/10/18

Jonathan Hall

Experimental Programme (at HSL)

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- WP3: Unignited releases focussing on dispersion / source term
- WP4: Ignition phenomena focussing on electrostatics / condensed phase initiation / rapid phase transition
- WP5: Combustion characteristics including semi-confined / congested regions

WP4

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- The key objective is to examine electrostatic charging in liquefied/multiphase mixtures; and ignition sensitivity of energetic multiphase mixtures of hydrogen and oxygen
  - **E4.3 Electrostatic measurement of cold plume (focussing on accidental spillage scenarios)**
  - **E4.5 Ignition of H2/condensed O2 phase**

WP4 - Electrostatic plume measurement

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Work Package	Experimental Subtask	Test No.	Experiment Title	Release Orifice	Insulated Pipe Length	Field Measurement Method
4	4.3	4.3.1 (Test 3.5.3)	Electrostatic plume measurement	¼”	1.0 m	Faraday cage
4	4.3	4.3.2 (Test 3.5.3)	Electrostatic plume measurement	¼”	1.0 m	Field meter
4	4.3	4.3.3 (Test 3.5.1)	Electrostatic plume measurement	1”	1.0 m	Faraday cage
4	4.3	4.3.4 (Test 3.5.1)	Electrostatic plume measurement	1”	1.0 m	Field meter
4	4.3	4.3.5	Electrostatic plume measurement	1”	4.0 m	Faraday cage
4	4.3	4.3.6	Electrostatic plume measurement	1”	4.0 m	Field meter

Some release conditions will be as for WP3, **3.5.1** and **3.5.3**

WP4 - Electrostatic plume measurement – Field meter

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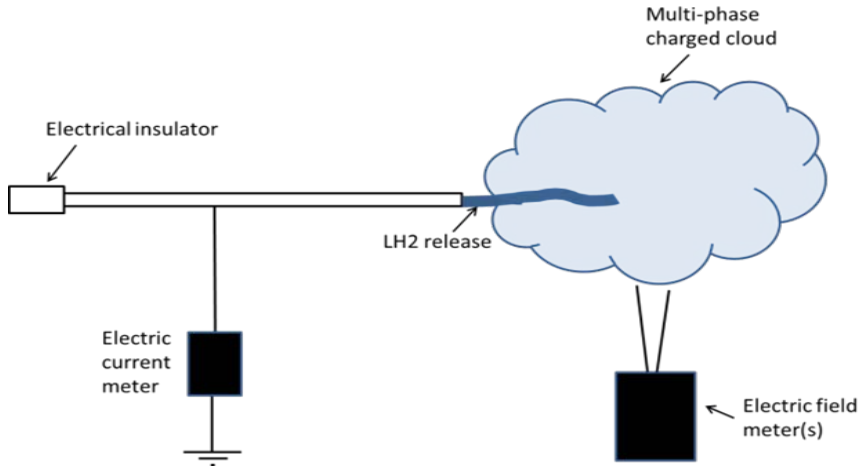
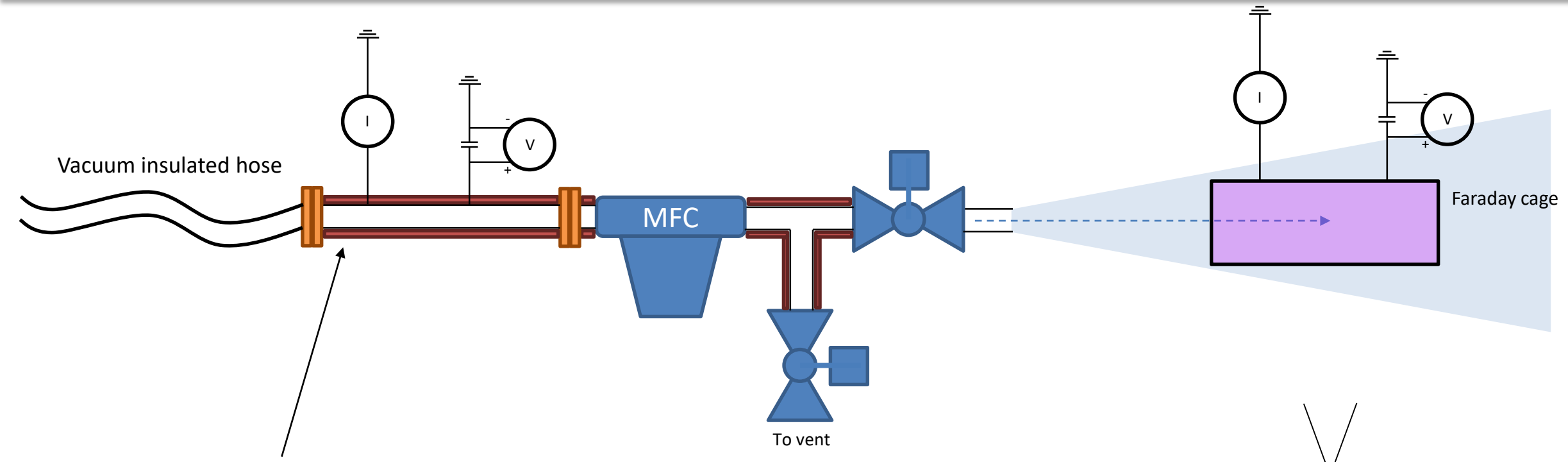
- Electrostatic measurements on pipeline, to estimate the charging current / charge density in bulk liquid flow



- To provide base level electrostatic measurements to draw practical implications from – i.e. comparison of propensity to ignite vs organics

WP4 – Test set up



Electrically isolated pipework, interchangeable 1 m or 4 m length

WP4 - Electrostatic plume measurement

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Instrumentation

- *Electrometer – measuring charge on pipework and second on faraday cage*
- *Electrostatic field meter – measuring background charge from plume/jet*
- *Local humidity from local weather station*

Infrastructure

- *1 m / 4 m long isolated section of pipe*
- *Shield plate for field meter*
- *Shielded cable from pipework to control room for electrometer*
- Faraday cage, dimensions 0.5 m * 0.5 m * 1.0 m

P&ID

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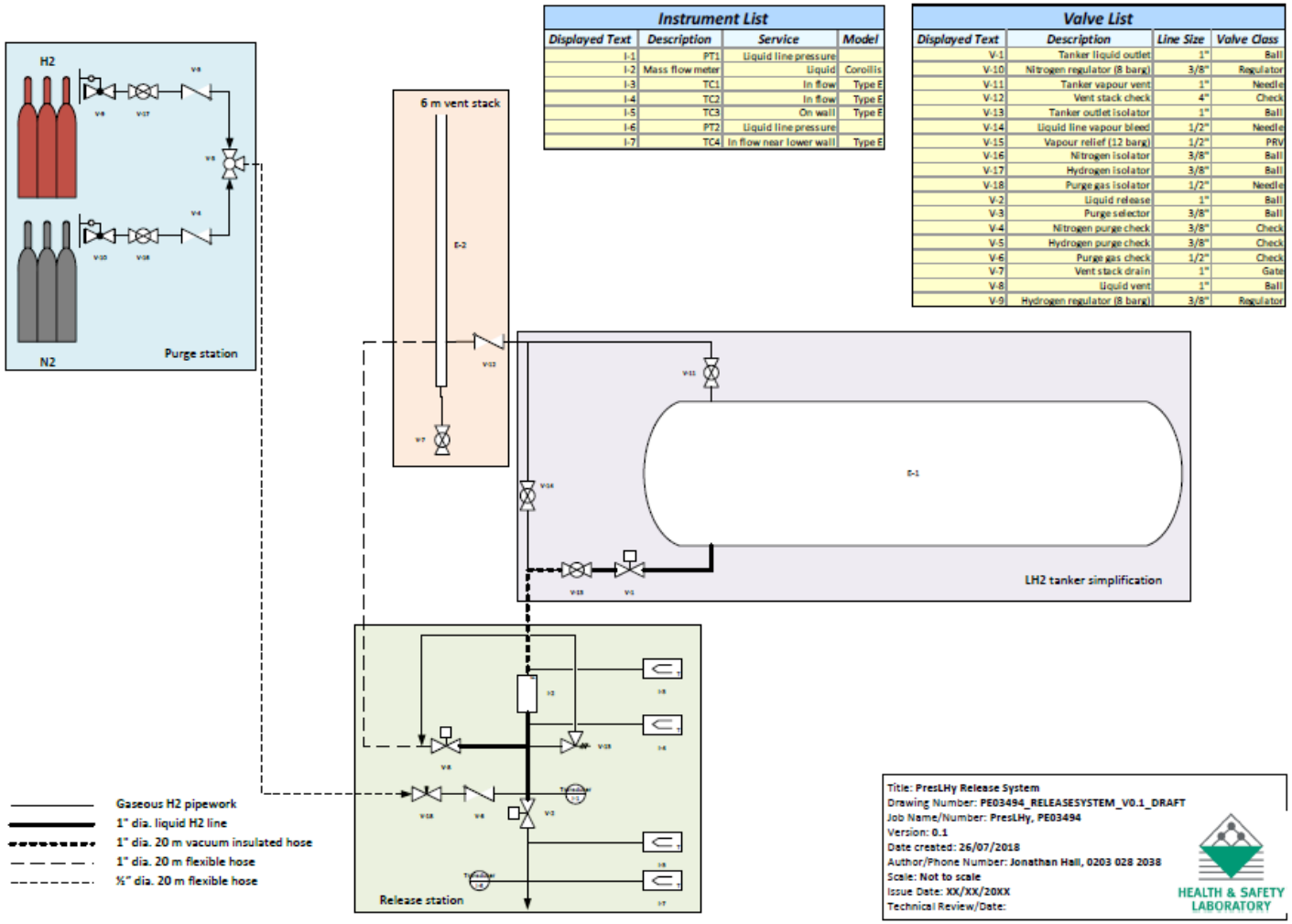

Instrument List

Displayed Text	Description	Service	Model
I-1	PT1	Liquid line pressure	
I-2	Mass flow meter	Liquid	Corollis
I-3	TC1	In flow	Type E
I-4	TC2	In flow	Type E
I-5	TC3	On wall	Type E
I-6	PT2	Liquid line pressure	
I-7	TC4	In flow near lower wall	Type E

Valve List

Displayed Text	Description	Line Size	Valve Class
V-1	Tanker liquid outlet	1"	Ball
V-10	Nitrogen regulator (8 barg)	3/8"	Regulator
V-11	Tanker vapour vent	1"	Needle
V-12	Vent stack check	4"	Check
V-13	Tanker outlet isolator	1"	Ball
V-14	Liquid line vapour bleed	1/2"	Needle
V-15	Vapour relief (12 barg)	1/2"	PRV
V-16	Nitrogen isolator	3/8"	Ball
V-17	Hydrogen isolator	3/8"	Ball
V-18	Purge gas isolator	1/2"	Needle
V-2	Liquid release	1"	Ball
V-3	Purge selector	3/8"	Ball
V-4	Nitrogen purge check	3/8"	Check
V-5	Hydrogen purge check	3/8"	Check
V-6	Purge gas check	1/2"	Check
V-7	Vent stack drain	1"	Gate
V-8	Liquid vent	1"	Ball
V-9	Hydrogen regulator (8 barg)	3/8"	Regulator

Title: PresLHy Release System
Drawing Number: PE03494_RELEASESYSTEM_V0.1_DRAFT
Job Name/Number: PresLHy, PE03494
Version: 0.1
Date created: 26/07/2018
Author/Phone Number: Jonathan Hall, 0203 028 2038
Scale: Not to scale
Issue Date: XX/XX/20XX
Technical Review/Date:

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WP4 - Ignition of H_2/condensed O_2 phase

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- Bespoke release conditions/set up.
- Condensed phase will be made up of pure oxygen on first pass, any ignitions may be repeated with a condensed phase made up of air.

Work Package	Experimental Subtask	Test No.	Experiment Title	Ignition Type
4	4.5	4.5.1	Ignition of H_2/condensed O_2 phase	Explosive detonator
4	4.5	4.5.2	Ignition of H_2/condensed O_2 phase	Electric spark, multiple heights
4	4.5	4.5.3	Ignition of H_2/condensed O_2 phase	Chemical ignitor, >10 kJ
4	4.5	4.5.4	Ignition of H_2/condensed O_2 phase	Mechanical, drop weight
4	4.5	4.5.5	Ignition of H_2/condensed air phase	Explosive detonator
4	4.5	4.5.6	Ignition of H_2/condensed air phase	Electric spark, multiple heights
4	4.5	4.5.7	Ignition of H_2/condensed air phase	Chemical ignitor, >10 kJ
4	4.5	4.5.8	Ignition of H_2/condensed air phase	Mechanical, drop weight
4	4.5	4.5.9	Rapid phase transition	Water deluge (fire hose)
4	4.5	4.5.10	Rapid phase transition	Water deluge (sprinkler)

WP5 - Combustion with congestion/confinement

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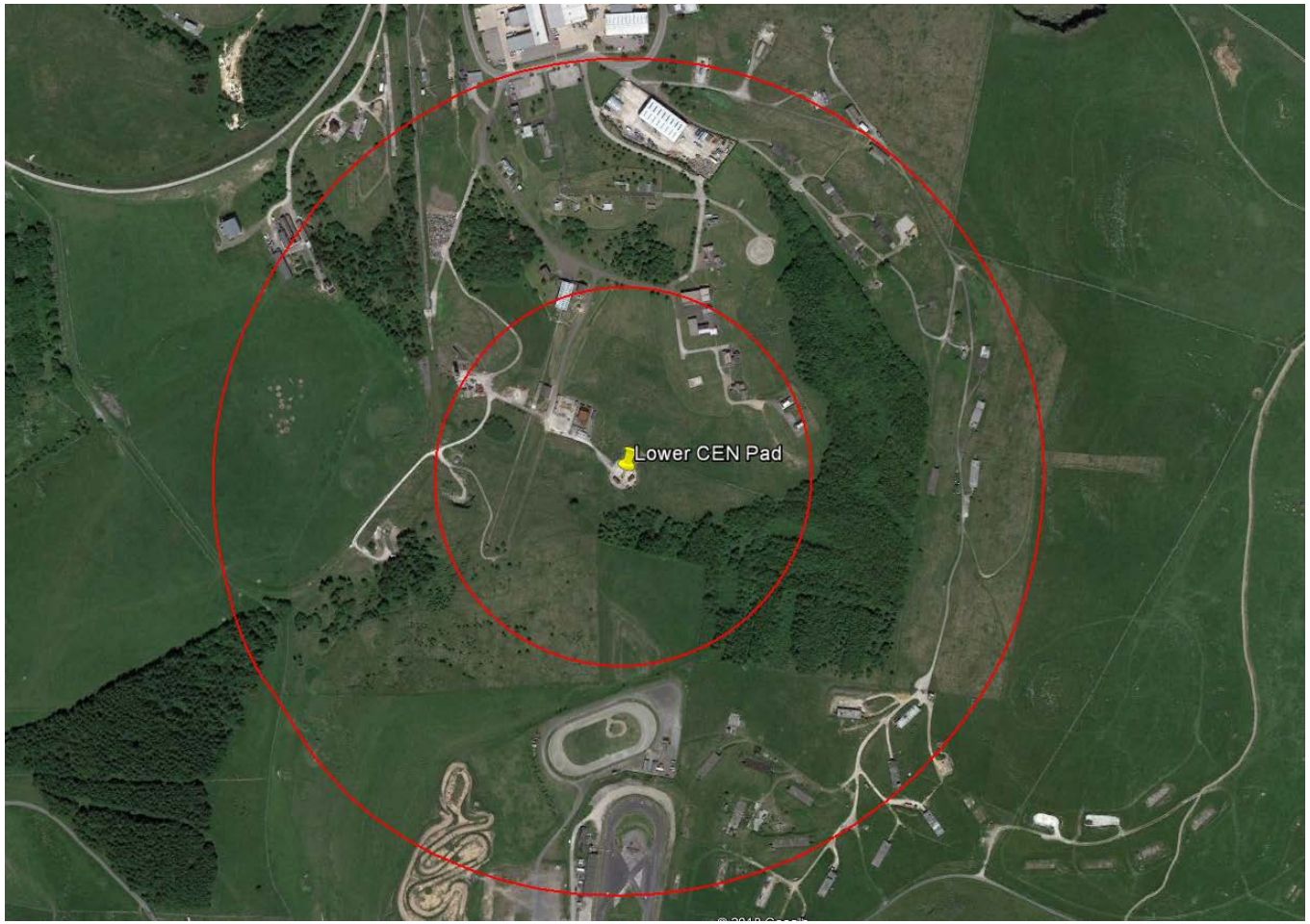
- Distance arcs of 215 m and 475 m
- Assuming 135 dB limit at extremes
- Equates to:
  - 0.137 kg TNT @ 215 m
  - 1.480 kg TNT @ 475 m



WP4 - Ignition of H_2/condensed O_2 phase

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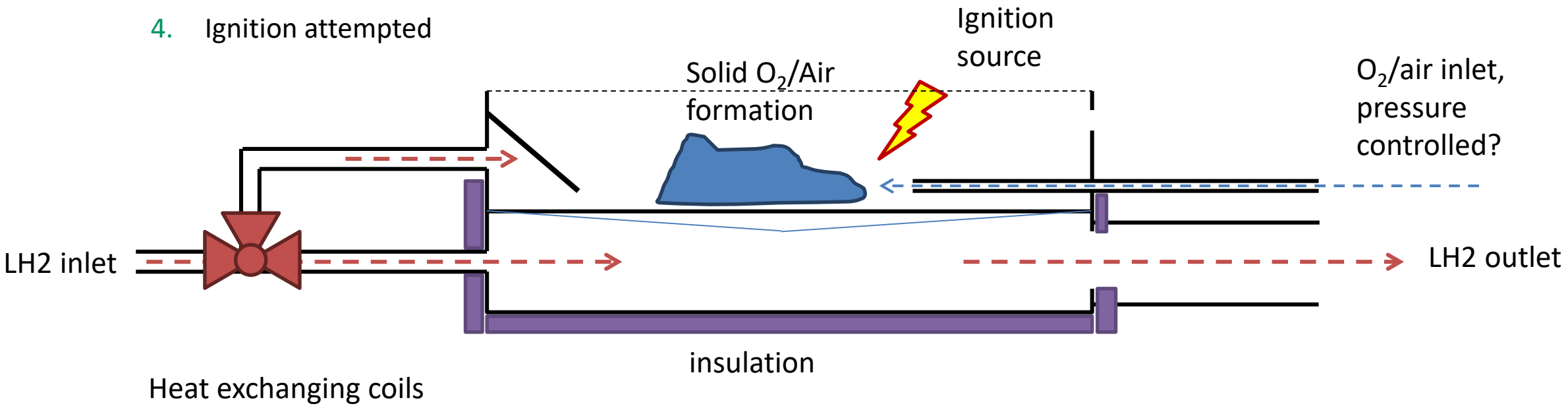
- Bespoke release conditions/set up
  1. LH2 fed into lower chamber until upper plate is cold
  2. O2/air fed onto top surface of plate to form solid deposition
  3. LH2 feed then turned onto top surface and deposition
  4. Ignition attempted



- Rapid phase transition tests could use same rig or simply spills onto the ground for longer

WP4 – Previous experiments

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- Used sample equivalent to 0.11 kg of TNT
- Previous NASA work used 0.024 kg of O_2 with LH_2 in excess, LH_2 quantity did not affect ignition sensitivity
- Used PU insulated PE containers
- Explosive yield = 2 kg TNT per 1 kg LH_2 + 0_2
- Therefore maximum of 0.15 kg of TNT = 0.075 kg LH_2 + 0_2

WP4 - Ignition of H_2/condensed O_2 phase

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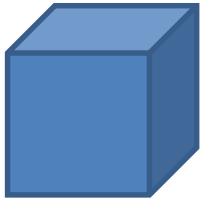
- The density of solid oxygen ranges from 21 cm^3/mol in the α-phase, to 23.5 cm^3/mol in the γ-phase. *(Roder, H. M. (1978). "The molar volume (density) of solid oxygen in equilibrium with vapor" (reprint). Journal of Physical and Chemical Reference Data. 7 (3): 949.)*
- *Therefore: 21* cm^3/mol = 0.0476 mol/cm^3
- *O_2 molar mass is 32 g/mol*
- *Density of solid O_2 = 32*0.0476* = 1.524 g/cm^3 = 1524 kg/m^3
- *If 0.024 kg of solid O_2 is generated that takes up 0.016 l of space*
- *If the remainder of 0.075 kg of mixture is LH^2, that leaves 0.045 kg of LH^2 (density 70 kg/m^3) which takes up 6.43e^{-4} m^3 or 0.64 l*

WP4 - Ignition of H_2/condensed O_2 phase

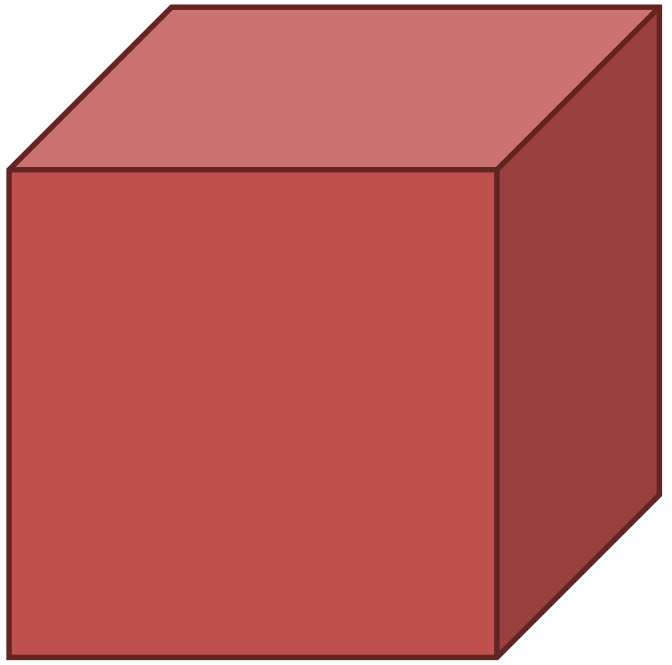
- If 0.5 x 0.5 m tray is used, 0_2 level = 0.064 mm, LH_2 level = 2.6 mm
- If 0.25 x 0.25 m tray is used, 0_2 level = 0.26 mm, LH_2 level = 10.3 mm

25 mm cube O2



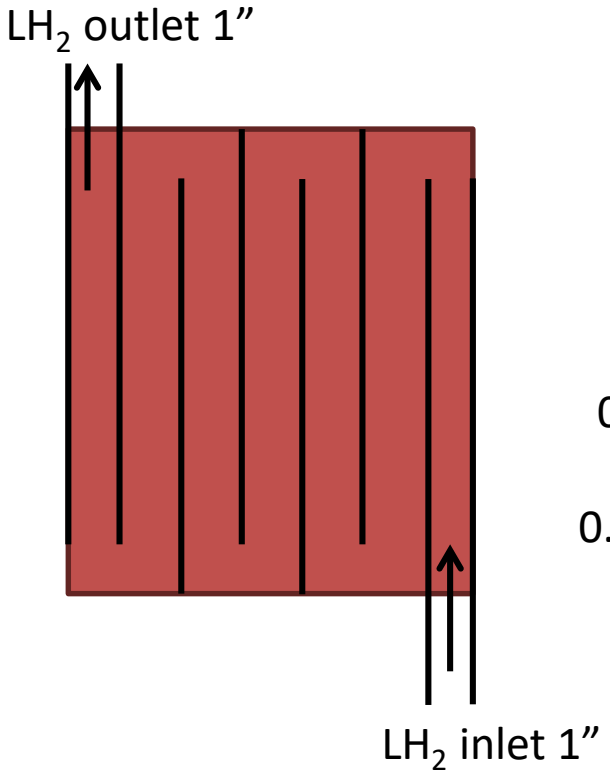
0.016 l, 0.000016 m^3, 0.024 kg

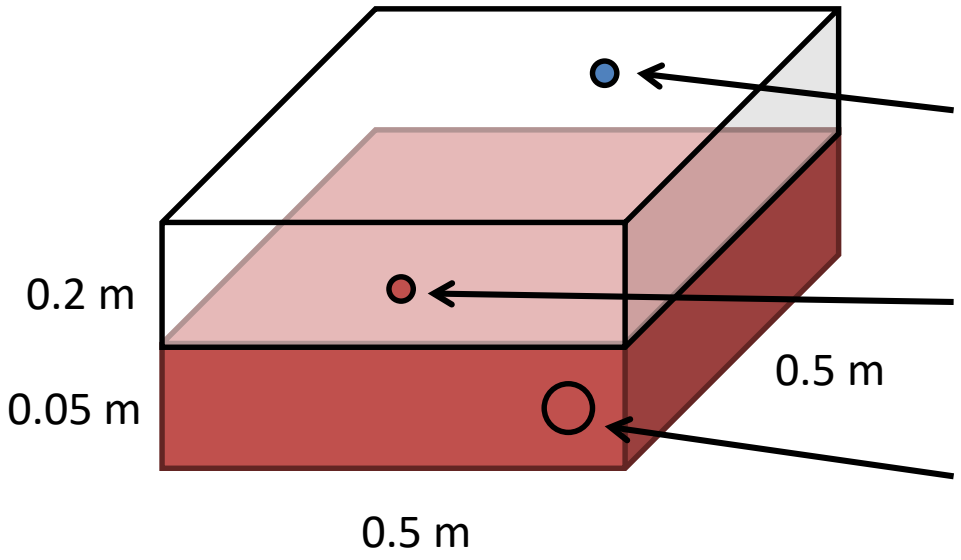
86 mm cube LH2



0.64 l, 0.000643 m^3, 0.045 kg

WP4 - Ignition of H_2/condensed O_2 phase





Reaction chamber O_2 inlet flow:
≈6 l/min with 2 mm inlet

Reaction chamber LH_2 inlet flow:
≈6 l/min with 2 mm inlet, 0.44 kg/min

Heat exchanger LH_2 inlet flow:
≈<350 l/min with 1”inlet

Reaction chamber LH2 inlet sized to give maximum allowable quantity in ≈30 secs. Total coverage of solid O_2 is required for most ignition sensitive mixture therefore surface area of rig adjusted to suit.

WP4 - Ignition of H_2/condensed O_2 phase

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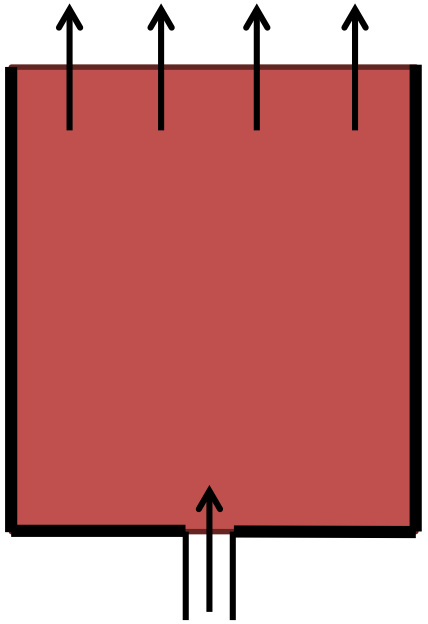
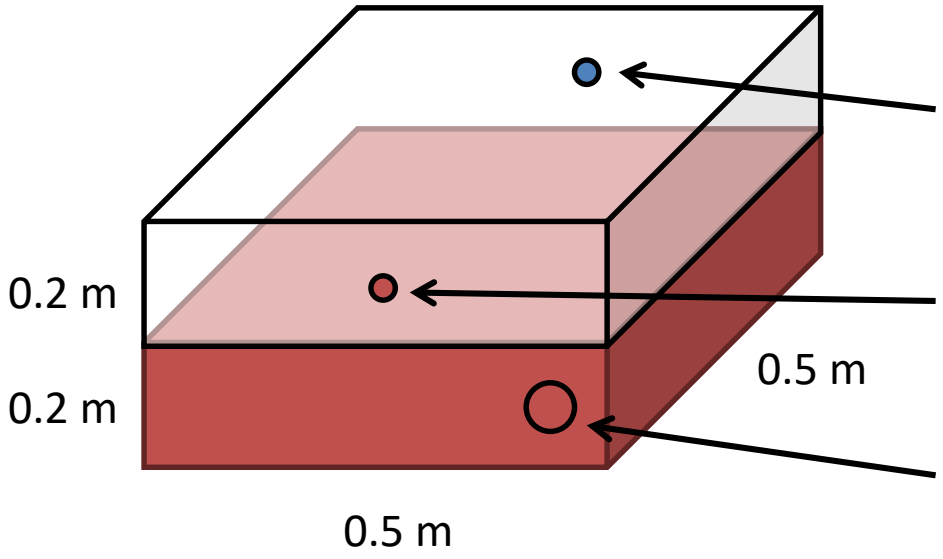
LH_2 outlet 0.2 x 0.5 m, 0.1 m^2



LH_2 inlet ½", 1.27e-4 m^2

Vent 800x larger than inlet, volume expansion of LH2 850-1



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WP4 - Ignition of H_2/condensed O_2 phase

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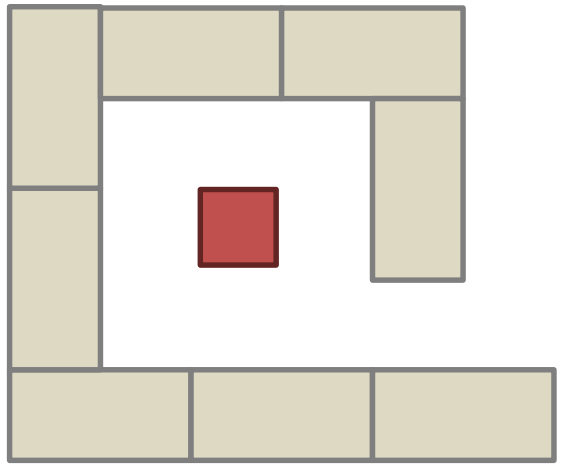
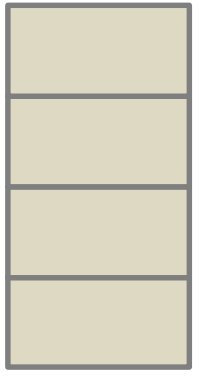
- Surround reaction chamber with concrete blocks
- Blast pressure measurement within the concrete walls



Plan view



Walls 3 blocks high

WP4 - Ignition of H_2/condensed O_2 phase

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- Energy of ignition of LH2/Condensed O_2 / N_2 based on an energy of impact source, Litchfield and Perlee:

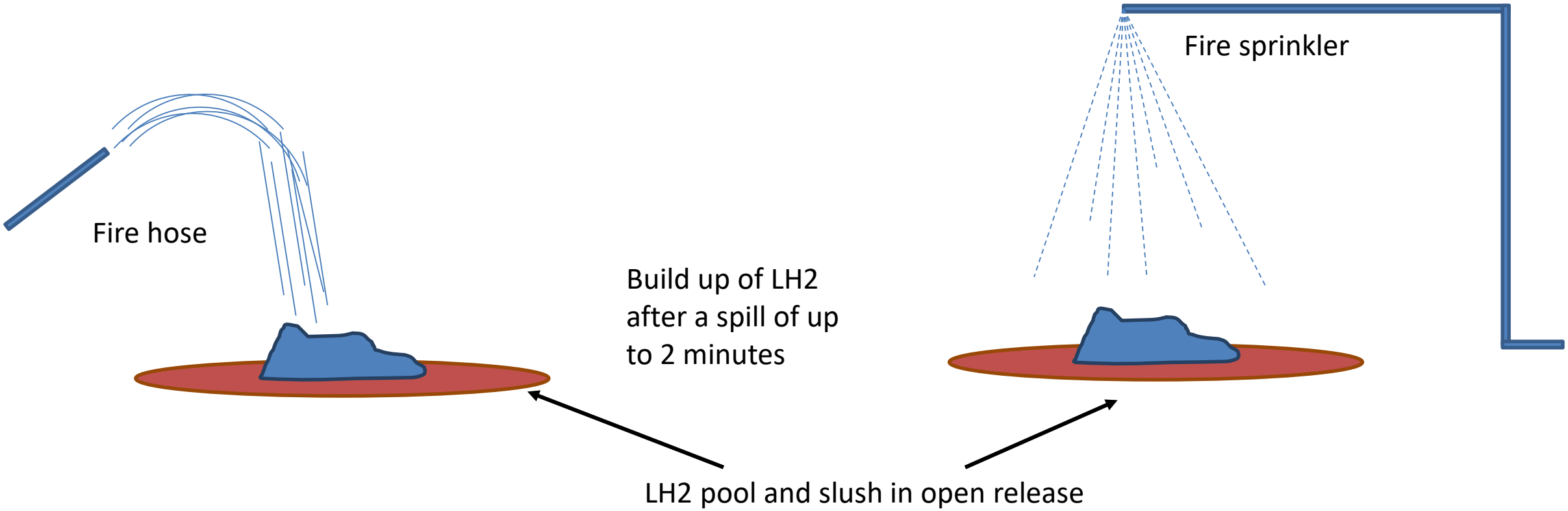
	Percent N2 in Condensate	Initiation		Failure	
		Velocity m/sec	Energy (kJ)	Velocity m/sec	Energy (kJ)
Pure O_2	0	506	1.80	506	1.80
	23	695	3.39	594	2.48
	47	1091	8.37	991	6.90
Air	78	-	-	1487	15.55

Initiated at energies at or above

Did not initiate at energies below

WP4 – Rapid phase transition

- Tests 4.5.9 and 4.5.10



WP4 - Ignition of H_2/condensed O_2 phase

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Instrumentation

- 2x blast pressure transducers within concrete enclosure walls (ranged 0-5 bara, 500 kHz logging rate)
- Audible sound meters at 50 m and 100 m approximately
- Remote ignition system with multiple outputs
- Thermocouples within reaction chamber/rig
- High speed video and IR

Infrastructure

- Reaction chamber/rig
- Protective concrete block wall around chamber
- Protective steel shield in front of release station 1 m wide x 2 m high

Gantt chart

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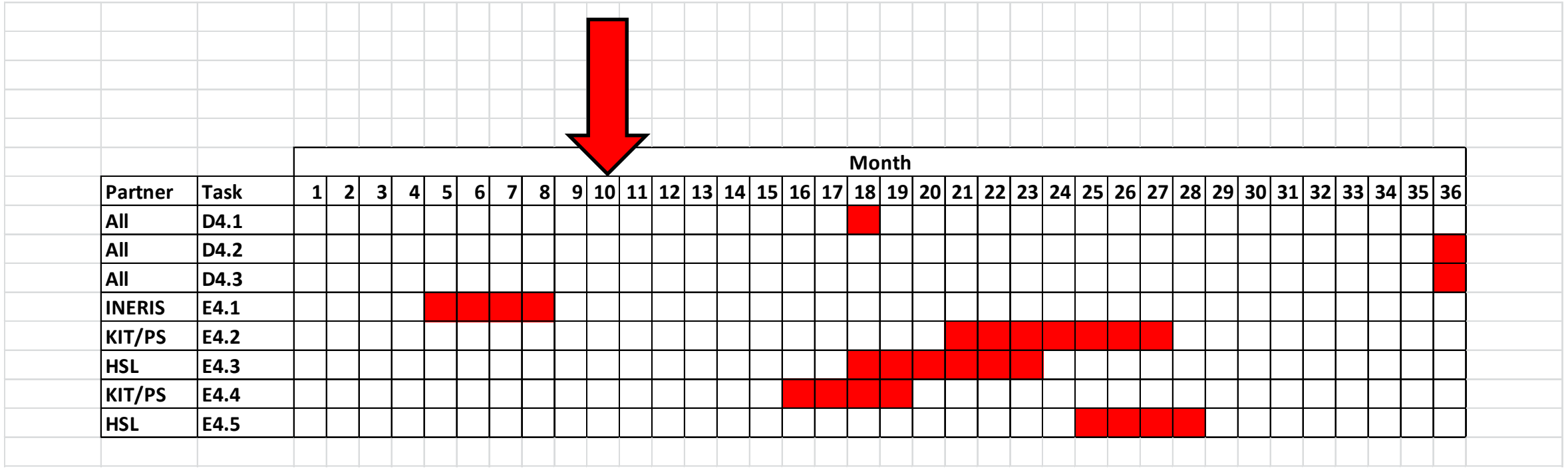

		Month																																	
Partner	Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
All	D4.1																																				
All	D4.2																																				
All	D4.3																																				
INERIS	E4.1																																				
KIT/PS	E4.2																																				
HSL	E4.3																																				
KIT/PS	E4.4																																				
HSL	E4.5																																				

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