PRESLHY

WP1 - Management

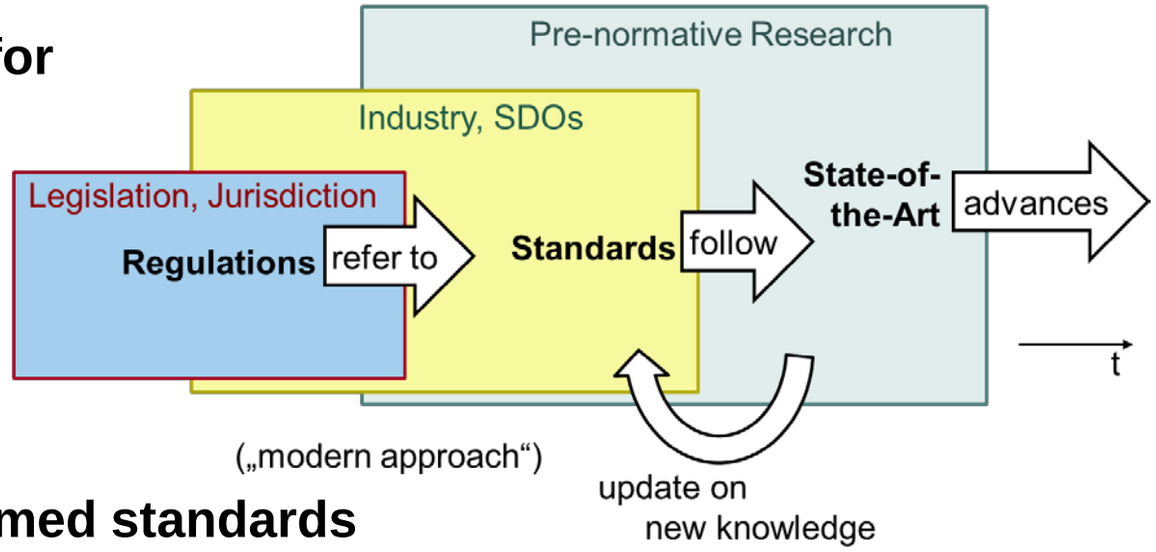
Air Liquide, Paris-Saclay, France, 16 October 2018

Pre-normative REsearch for Safe use of Liquid HYdrogen

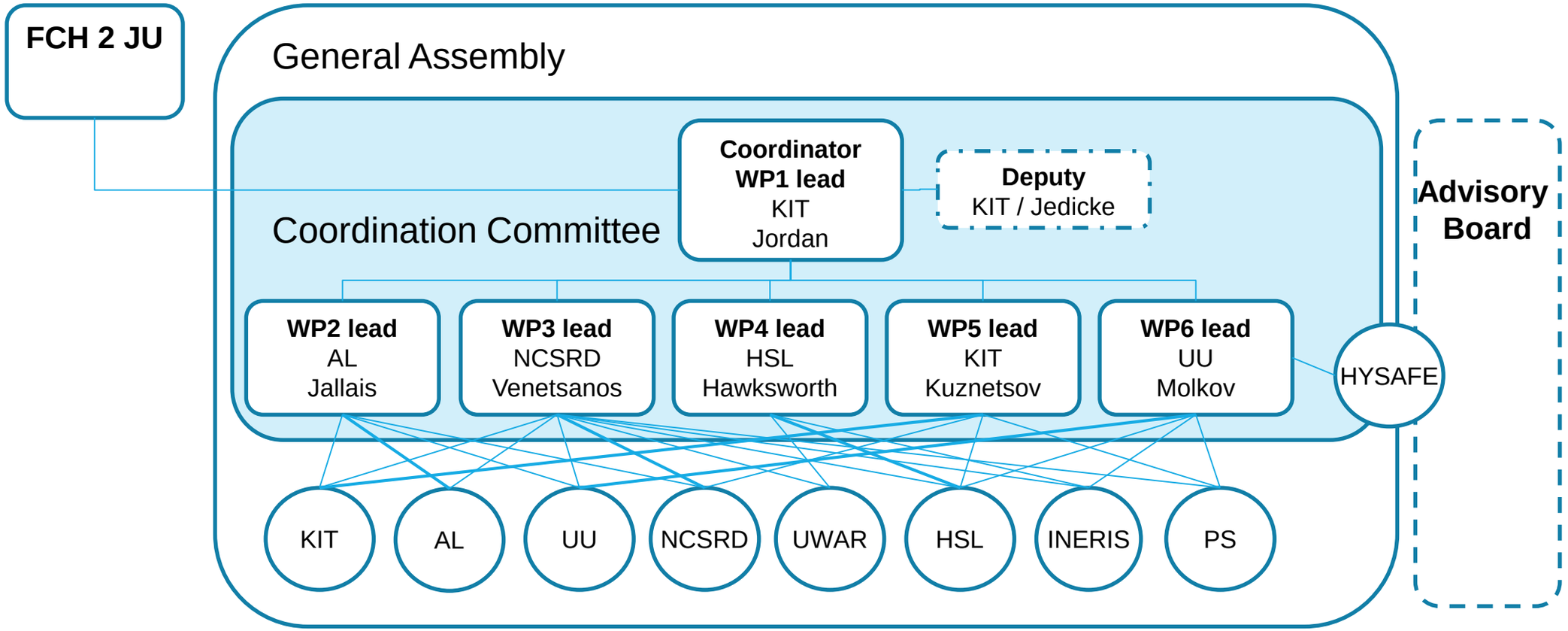
KIT Karlsruher Institut für Technologie
Air Liquide
HEALTH & SAFETY LABORATORY
hySafe INTERNATIONAL ASSOCIATION FOR HYDROGEN SAFETY
INERIS
ΔΗΜΟΚΡΙΤΟΣ
Pro-Science
Ulster University
WARWICK THE UNIVERSITY OF WARWICK

Objectives

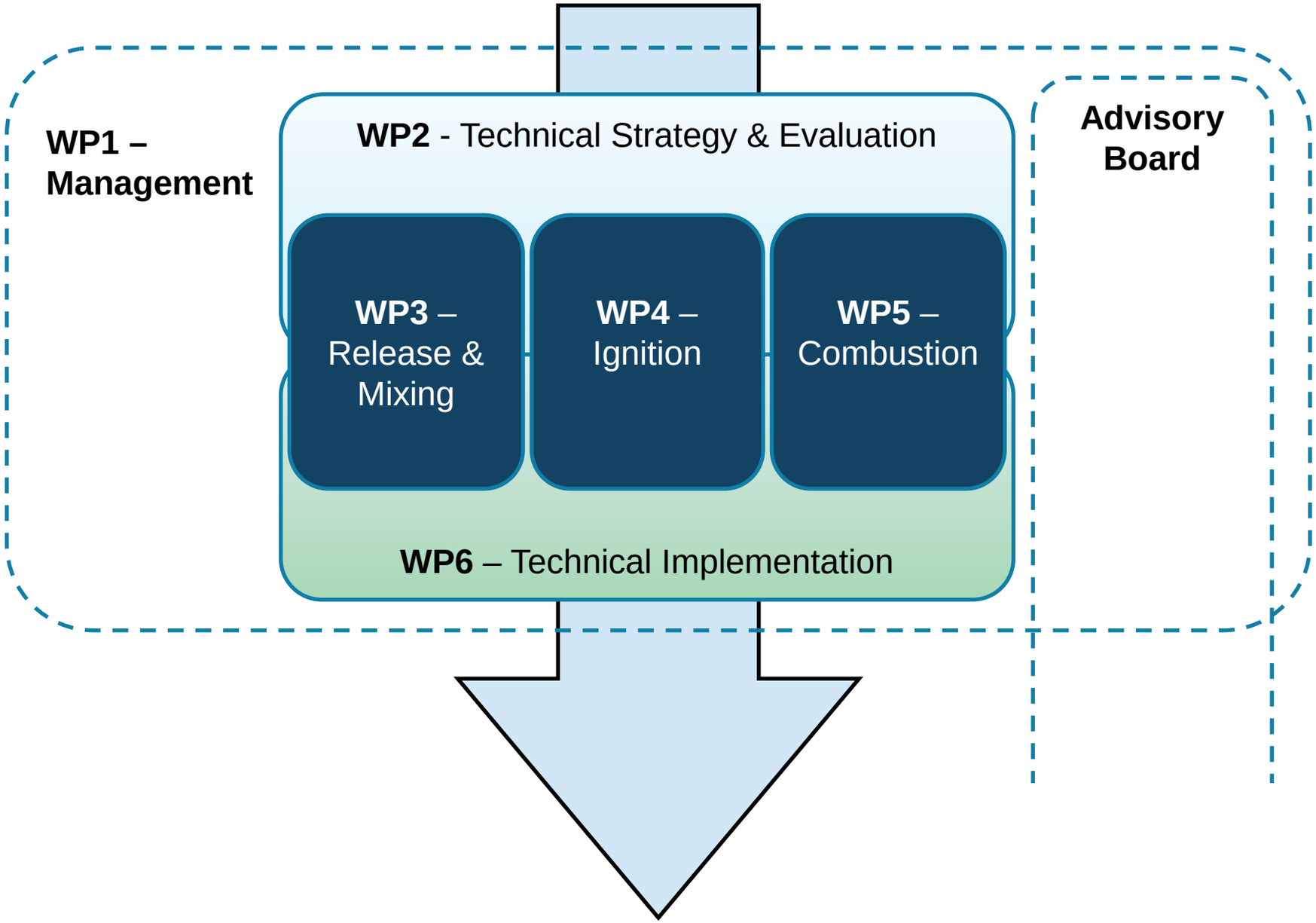
- Report on the **initial state-of-the-art and knowledge gaps** with priorities related to the envisaged use of LH2
- Execute adjusted **experimental program** addressing release, ignition and combustion phenomena with highest priorities
- Document and publish detailed, aggregated and interpreted data in a FAIR way
- Develop **suitable models and engineering correlations** and integrate them in a suitable open risk assessment toolkits
- Provide **enhanced recommendations for safe design and operations** of LH2 technologies
- **Support international SDOs** in
  - **updating of existing standards** or
  - developing of **new international performance based and risk informed standards**
- Document and disseminate the **enhanced state-of-the-art**

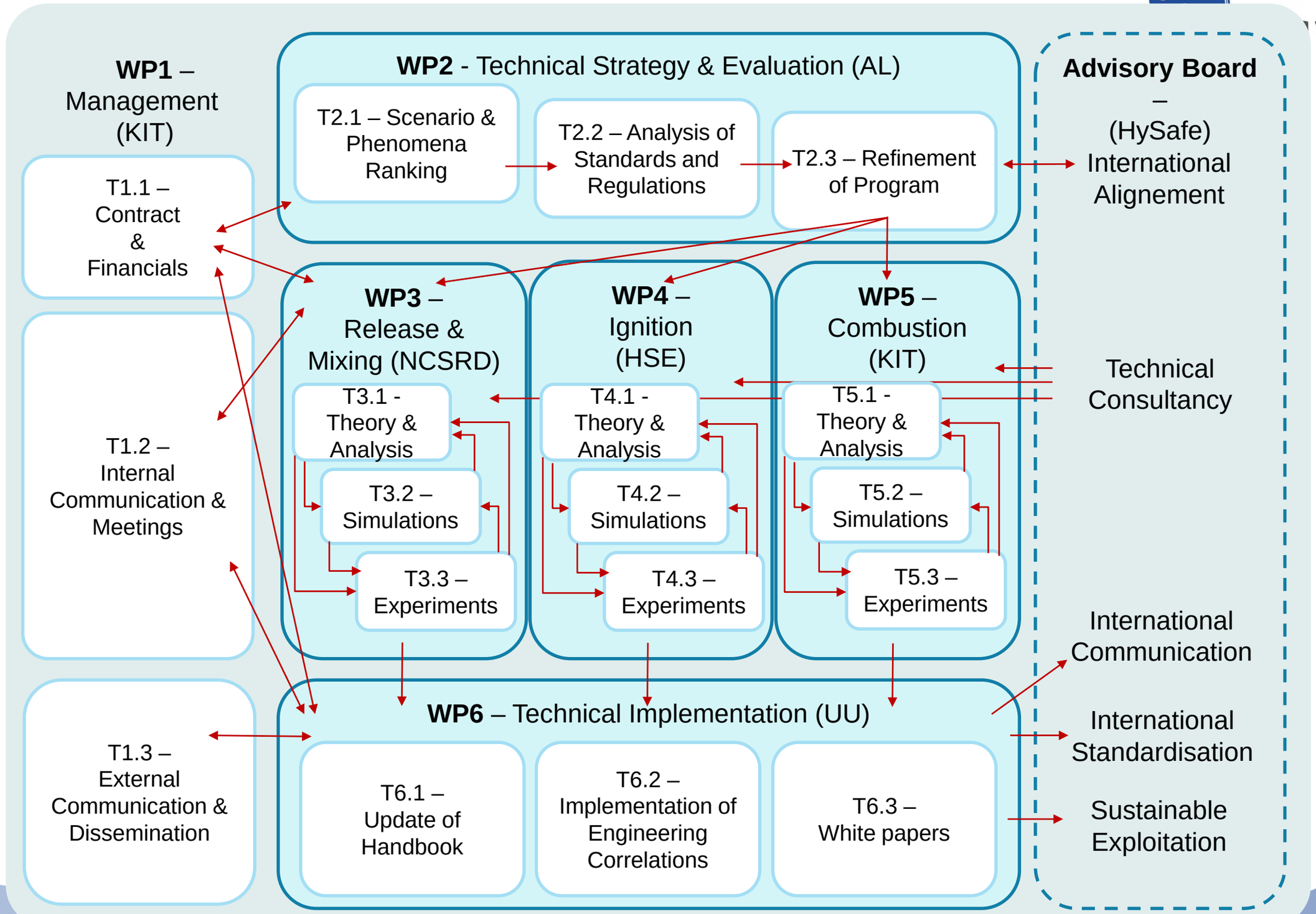


Governance

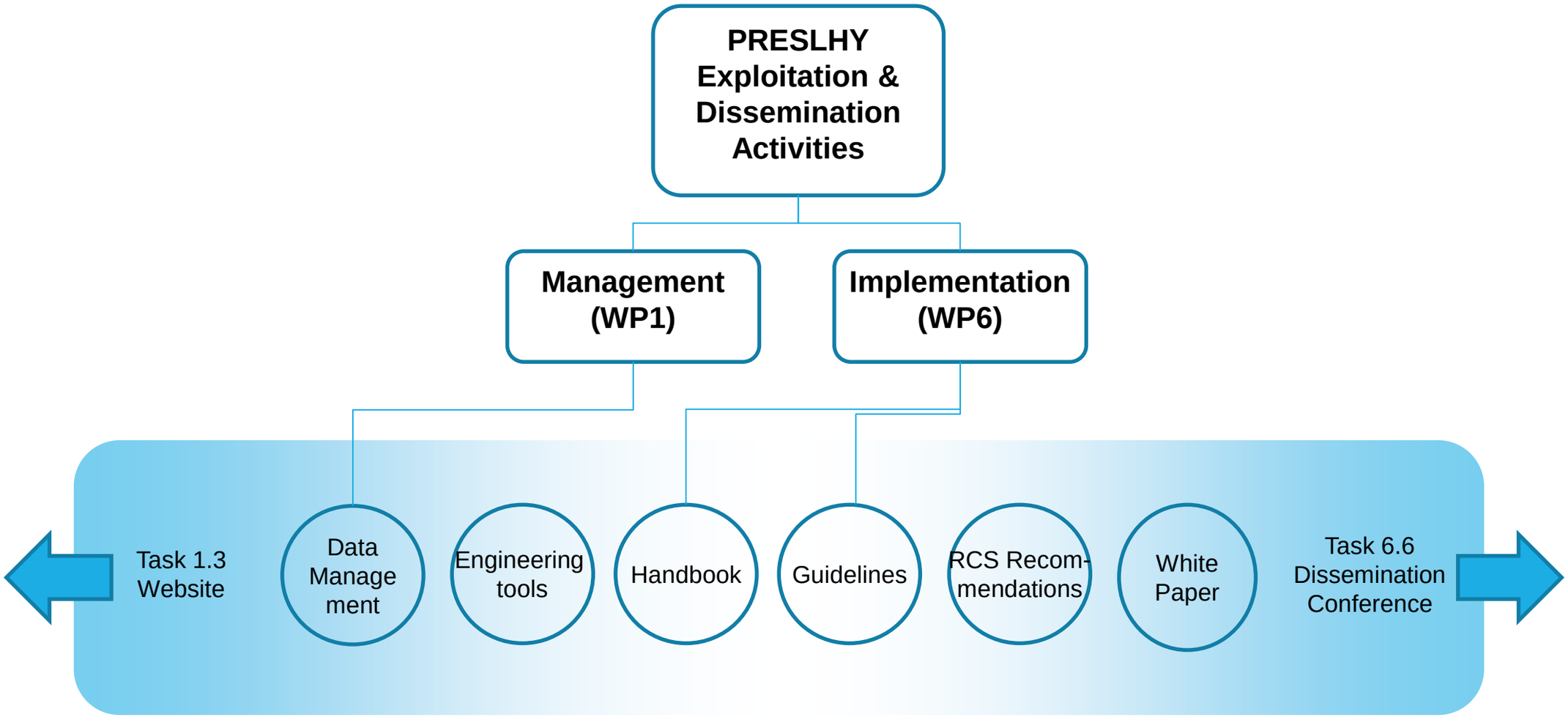

FCH 2 JU
General Assembly
Coordination Committee
Coordinator
WP1 lead
KIT
Jordan
Deputy
KIT / Jedicke
Advisory Board
WP2 lead
AL
Jallais
WP3 lead
NCSRD
Venetsanos
WP4 lead
HSL
Hawksworth
WP5 lead
KIT
Kuznetsov
WP6 lead
UU
Molkov
HYSAFE
KIT
AL
UU
NCSRD
UWAR
HSL
INERIS
PS

General Approach

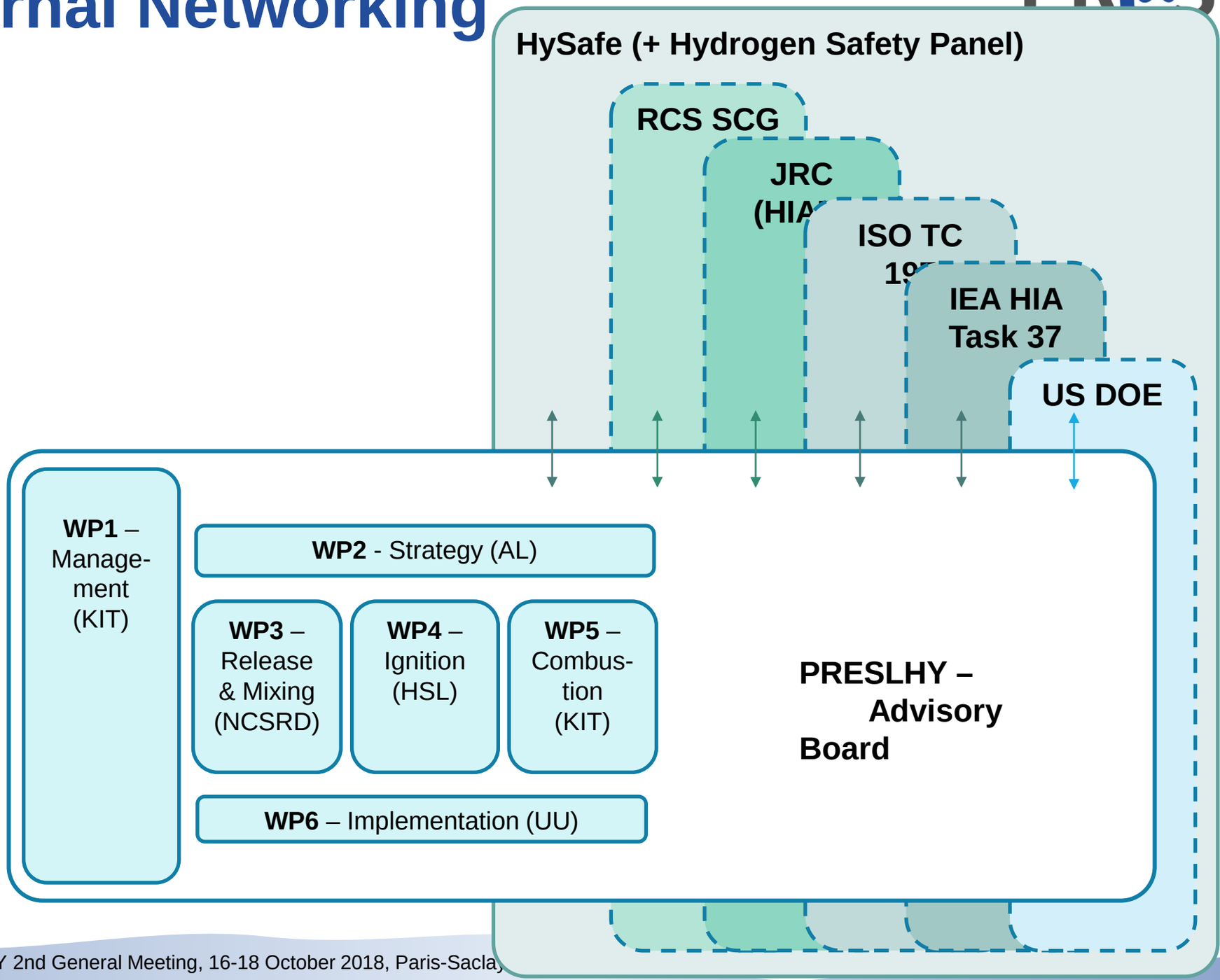



WP1 – Management (KIT)
T1.1 – Contract & Financials
T1.2 – Internal Communication & Meetings
T1.3 – External Communication & Dissemination
WP2 - Technical Strategy & Evaluation (AL)
T2.1 – Scenario & Phenomena Ranking
T2.2 – Analysis of Standards and Regulations
T2.3 – Refinement of Program
WP3 – Release & Mixing (NCSRD)
T3.1 - Theory & Analysis
T3.2 – Simulations
T3.3 – Experiments
WP4 – Ignition (HSE)
T4.1 - Theory & Analysis
T4.2 – Simulations
T4.3 – Experiments
WP5 – Combustion (KIT)
T5.1 - Theory & Analysis
T5.2 – Simulations
T5.3 – Experiments
WP6 – Technical Implementation (UU)
T6.1 – Update of Handbook
T6.2 – Implementation of Engineering Correlations
T6.3 – White papers
Advisory Board – (HySafe)
International Alignement
Technical Consultancy
International Communication
International Standardisation
Sustainable Exploitation

Outreach


PRESLHY Exploitation & Dissemination Activities
Management (WP1)
Implementation (WP6)
Task 1.3 Website
Data Manage ment
Engineering tools
Handbook
Guidelines
RCS Recom-mendations
White Paper
Task 6.6 Dissemination Conference

External Networking



WP1 - Update

- Update of project officer: explanation of delay, reminder of due reference (logo of FCH 2 JU at workshop etc)
- CA signed by all partners → copies will be distributed in M10
- ISO/TC197 PWI: „Safe Use of LH2 in Non-Industrial Settings“
  (to be presented at Day 1 6th December 2018 at 27th plenary meeting in Vancouver)

8. Documents Published: ISO 19880-3:2018 *Gaseous hydrogen – Fuelling stations – Part 3: Valves,* developed by WG 20 with Shogo Watanabe, from Japan as convenor and Yuko Yasutake as secretary.
9. Systematic Reviews and Documents more than six years old:
10. New work item proposals (PWI : Safe Use of LH2 in Non-Industrial Settings, Dr. Thomas Jordan, KIT, PRESLHY)

Day Two (Friday Dec. 7th, 2018) 09 h to 14 h

11. Liaisons and reports of liaisons

11.1 Existing Liaisons (ex. ISO/TC 22 SC 37, TC 22/SC 41, TC 58/SC 2, TC 58/ SC 3 (N), TC 158, TC 220, IEC TC 105, CEN/TC 268 (N), CEN-CLC/TC6 (N), etc.)

WP1 - Update

- Input for poster at Review Meeting
  (to be delivered in coop. with WP6)

- Identification of a safety distance benchmark „LH2 based HFS“
  (WP6 to organise benchmark?)

- Next site visit:
  TUD (Haberstroh) + Linde Liquefier Leuna
  When:
  2 days in Week 6 or 7 (first two weeks in M14 = February 2019)

Next Meetings

Date (Project Month)	Meetings / Venue	Host / Organiser	*(Internal)* Workshop Topic
1	**Kick-off Meeting** (1st Project Meeting) Karlsruhe, Germany	KIT	*Optical Measurement and Electrostatics*
4	**Initial Workshop** Brussels, Belgium	HYSAFE	**Research Priorities Workshop on LH2**
9	**2nd Project Meeting** Paris, France	AL/ INERIS	*Cryo-Techniques*
14	**3rd Project Meeting** Buxton, UK	HSL	*P,T, flow measurement*
21	**4th Project Meeting** In combination with ICHS2019 Albuquerque, USA	HYSAFE/ Sandia National Lab	*Two phase measurements*
26	**5th Proje** Athens, Gre	NCSRD	*Numerical Tools, CFD and Risk Assessment*
33			
35			

To be combined with site visit? Or delayed one month?

In the contract the 4th project meeting in September 2019 was announced in combination with the ICHS2019 (in the preparation phase we were assuming Sandia/Albuquerque to host, but now it will be in Adelaide South Australia).
I recommend to host the meeting in Europe, but if you believe there is a good reason to do the meeting there and you confirm there is budget for this, I will not have any objection and the costs will be considered eligible -taking into account this is mentioned in the GA – but please let me know in advance if this is your final decision.

Advisory Board

Name	Company Institution	Nation	Expertise
Derek Miller	Air Products	US	Industry
Andrei Tchouvelev	AVT	CAN	General Expert, SDO (ISO), SME
Klaus Schäfer	DLR	D	Large Scale User, General Expert
Franz Grafwallner	ET	D	Aerospace Expert
Trygve Skjold	GexCon	N	Modelling Expert, SME
Karl Verfondern	Jülich	D	General Expert, Research
Shoji Kamiya	KHI	JP	Industry, Naval application
Salvador Aceves	LLNL	US	Research, Cryo-compressed
Lee Philips	Shell	UK	Industry
Ethan Hecht	SNL	US	Research
Christoph Haberstroh	Uni Dresden	D	Cryo
Olav Hansen	**Loyds**	**N**	**General Expert, Naval, Insurance**
Gerd-Michael Würsig	*[illegible]*	*D*	*Insurance, Naval application*
Pietro Moretto	*JRC*	*[illegible]*	*EC, Research*
Volker Schröder	*BAM*	*D*	*[illegible]*
Steve Woods	*NASA*	*US*	*Research, [illegible]*

New, by electronic voting

Proposal for new Advisory Board Members

- Andreas Haberzettl, DLR Germany (RPW participant)
- Bernhard Strauss, ET EnergieTechnologie Germany and
- Etienne Studer, CEA France

Gantt Chart

today

		1st period (month 1-18)												2nd period (month 19-36)																							
	PRESLHY schedule	Year 1												Year 2												Year 3											
	Work package/task title	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
WP1	Management of the Project and Consortium	Kick Off Meeting																				Midterm															
Task 1.1	Contractual, administrative and financial project management							continuous work on demand																		continuous work on demand											
Task 1.2	Data Management Plan						D1.3						D1.9												D1.10												D1.11
Task 1.3	Internal communication and meetings	D1.1								D1.4					D1.5							D1.6					D1.7									D1.8	
Task 1.4	External communication, project website			D1.2																																	
WP2	Technical Strategy and State-of-the-Art																																				
Task 2.1	State-of-the-Art			D2.2			D2.5																														
Task 2.2	Analysis of Standards and Regulation			D2																																	
Task 2.3	Research Priorities Workshop				D2.4																																
Task 2.4	Refinement of the Program				D2.3		D2.6													continuation on demand																	
WP3	Phenomena Release and Mixing																																				
Task 3.1	Theory and Analysis																		D3.1																		
Task 3.2	Simulations																																				D3.2
Task 3.3	Experiments											D3.4								D3.5			D3.6														D3.3
WP4	Phenomena Ignition																																				
Task 4.1	Theory and Analysis																		D4.1																		
Task 4.2	Simulations																																				D4.2
Task 4.3	Experiments											D4.4											D4.7			D4.6			D4.5		D4.8					D4.3
WP5	Phenomena Combustion																																				
Task 5.1	Theory and Analysis																		D5.1																		
Task 5.2	Simulations																																				D5.2
Task 5.3	Experiments													D5.5		D5.4										D5.6								D5.7		D5.3
WP6	Implementation - Exploitation and Dissemination																																				
Task 6.1	Handbook of Hydrogen Safety: chapter on LH2 safety																																	D6.1			
Task 6.2	Guidelines for safe design and operation of LH2 infrastructure																																		D6.2		
Task 6.3	Recommendations for RCS																																		D6.3		
Task 6.4	Engineering correlations and tools																																		D6.5		
Task 6.5	White Paper on the use of LH2																																		D6.4		
Task 6.6	Dissemination Conference						D6.6												D6.7																		D6.8/D6.9
		1st period (month 1-18)												2nd period (month 19-36)																							
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Table of Deliverables at M10

Number	Deliverable (number)	Deliverable name	Work package number	Short name of lead participant	Type	Dissemination level	Delivery date (month)
D1	D1.1	Kick-off Meeting	1	KIT	OTHER	CO	1
D2	D1.2	Website including internal communication tools	1	KIT	DEC	PU	3
D12	D2.1	RCS Analysis	2	HySafe	REPORT	PU	3
D13	D2.2	State of the Art Report	2	AL	REPORT	PU	3
D14	D2.3	LH2 installation description	2	AL	REPORT	PU	4
D15	D2.4	LH2 Research Priorities Workshop	2	HySafe	OTHER	PU	4
D16	D2.5	Phenomena Identification and Ranking Table Analysis	2	AL	REPORT	PU	4
D17	D2.6	Refined Work Program	2	AL	REPORT	PU	5
D3	D1.3	Data Management Plan Version 1.0 - Draft	1	KIT	ORDP	PU	6
D44	D6.6	Plan for Dissemination, Communica	6	ULster	REPORT	PU	6

today

Number	Deliverable (number)	Deliverable name	Work package number	Short name of lead participant	Type	Dissemination level	Delivery date (month)
D4	D1.4	2nd Project Meeting	1	KIT	OTHER	CO	9
D21	D3.4	Summary of experiment series E3.1 (Discharge) results	3	PS	REPORT	CO	11
D27	D4.4	Summary of experiment series E4.1 (General ignition) results	4	INERIS	REPORT	CO	11
D9	D1.9	1st Annual Data Reporting	1	KIT	REPORT	CO	12
D5	D1.5	3rd Project Meeting	1	KIT	OTHER	CO	14
D36	D5.5	Summary of experiment series E5.2 results	5	PS	REPORT	CO	14
D35	D5.4	Summary of experiment series E5.1 results	5	PS	REPORT	CO	15
D18	D3.1	Theory and Analysis of cryogenic hydrogen release and dispersion	3	NCSRD	REPORT	PU	18

		1st period (month 1-18)												2nd period (month 19-36)																							
	PRESLHY schedule	Year 1												Year 2						Year 3																	
	Work package/task title	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
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Task 2.4	Refinement of the Program																			continuation on demand																	
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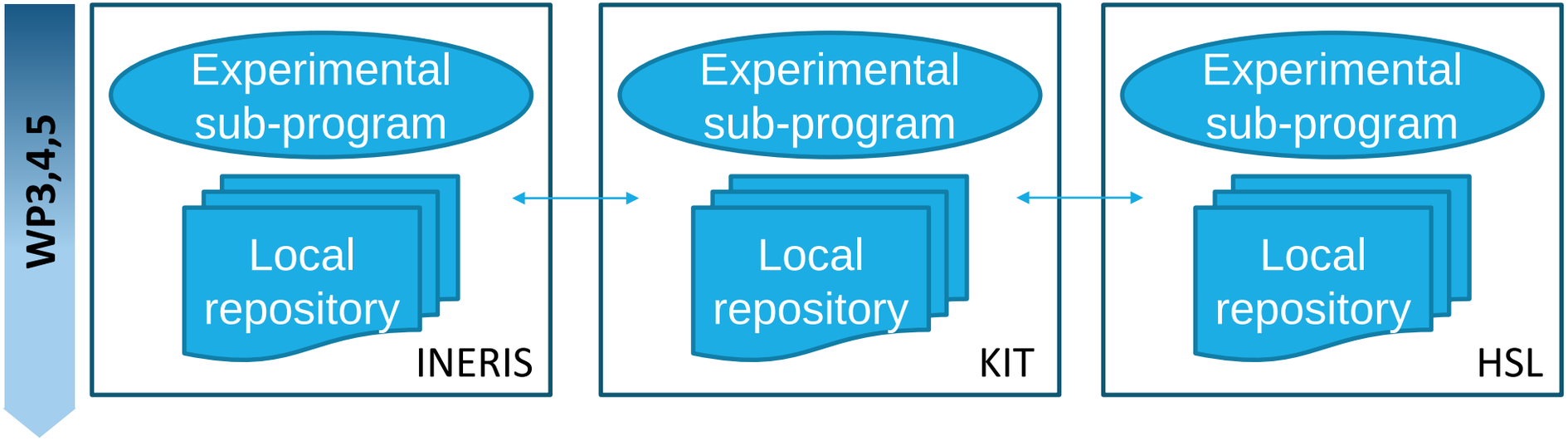
Task 3.1	Theory and Analysis																																				
Task 3.2	Simulations																																				
Task 3.3	Experiments					M1			M2				M3	M5			M4			M6																	
WP4	Phenomena Ignition																																				
Task 4.1	Theory and Analysis																																				
Task 4.2	Simulations																																				
Task 4.3	Experiments					M7			M8								M13		M11	M14		M9		M12		M15		M10		M16						
WP5	Phenomena Combustion																																				
Task 5.1	Theory and Analysis																																				
Task 5.2	Simulations																																				
Task 5.3	Experiments					M19			M17			M20	M18						M21			M22				M23						M24					
WP6	Implementation - Exploitation and Dissemination																																				
Task 6.1	Handbook of Hydrogen Safety: chapter on LH2 safety												M25																								
Task 6.2	Guidelines for safe design and operation of LH2 infrastructure														M26																						
Task 6.3	Recommendations for RCS																												M30								
Task 6.4	Engineering correlations and tools																								M29												
Task 6.5	White Paper on the use of LH2																		M27																		
Task 6.6	Dissemination Conference																						M28														
		1st period (month 1-18)												2nd period (month 19-36)																							
		Year 1												Year 2						Year 3																	
	Work package/task title	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

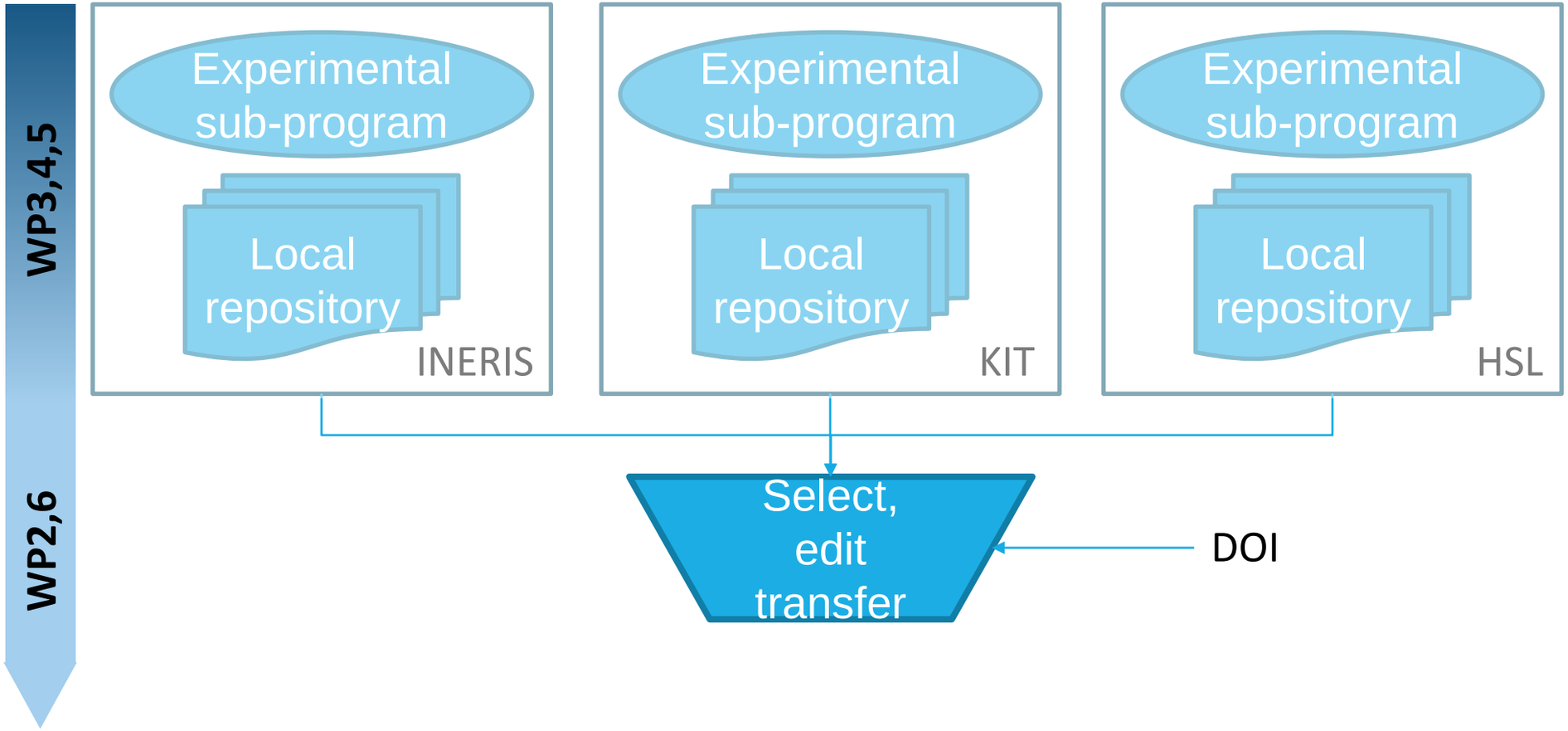
Deliverable 1.3 – Data Management Plan – Version 1.5

Table of Contents

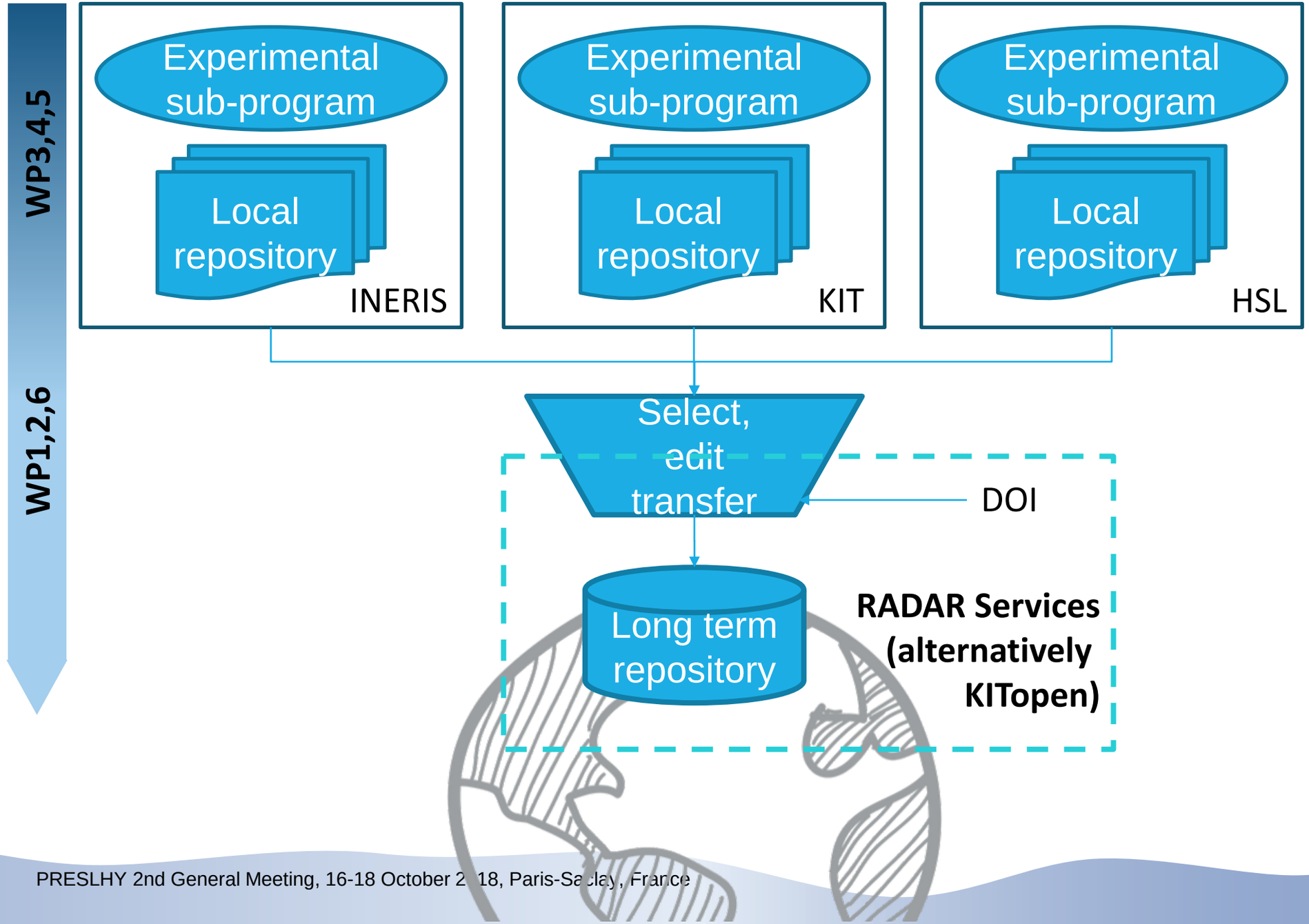
DMP - Internal Data Management



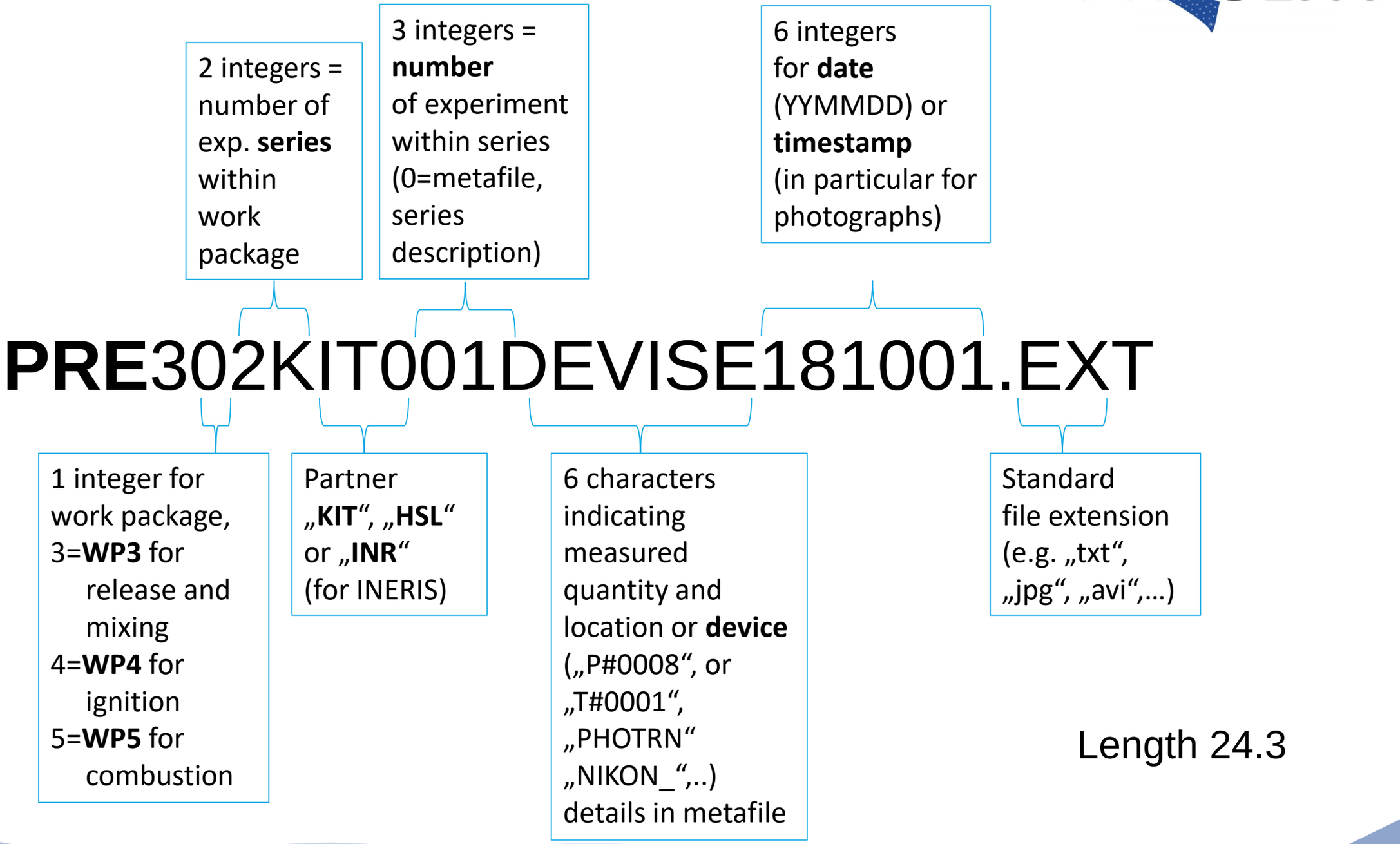
DMP - Preparing



DMP - Preparing



DMP – File Name Convention



Length 24.3

DMP – Metafile Template p.1/2

Pre-normative REsearch for Safe use of Liquid HYdrogen

PRESLHY-WP/Exp./Inst.	Phenomenon:	Issue addressed/Objective
WP3/E3.1/Pro-Science	Small Scale Multiphase Release	Discharge Coefficients of pressurized or LH2 Releases

Experiment Documentation Sheet

Experimental Set-Up

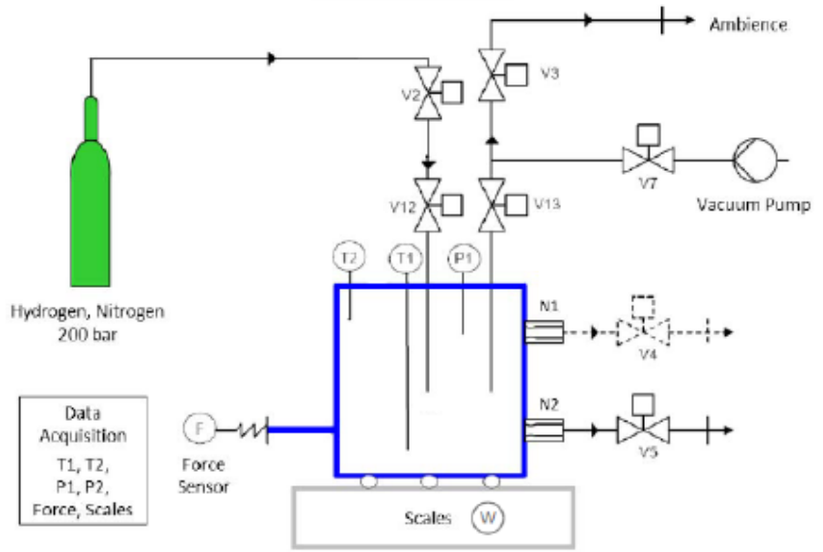


Fig. 1: Sketch of the DisCha-Facility with instrumentation (relevant drawings of vessel and nozzles used can be found in appendix A1).

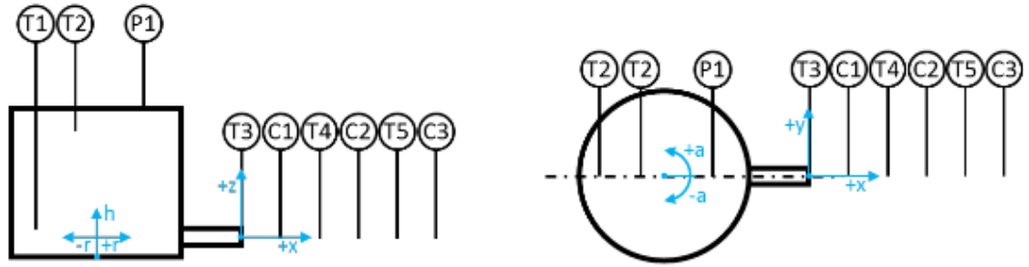


Fig. 2: Sketch of sensor positions inside and outside the DisCha-vessel.

Tab. 1: Sensor positions inside and outside the DisCha-vessel

Sensor	r [mm]	h [mm]	a [°]
T1	-60	30	180
T2	-40	110	180
P1	40	140	0

Sensor	x [mm]	y [mm]	z [mm]
T3	0	0	0
T4	100	0	0
T5	200	0	0
C1	300	0	0
C2	400	0	0
C3	500	0	0

DMP – Metafile Template p.2/2

Pre-normative REsearch for Safe use of Liquid HYdrogen

PRESLHY-WP/Exp. Number:	Phenomenon:	Issue addressed/Objective
WP3/E3.1	Small Scale Multiphase Release	Discharge Coefficients of pressurized or LH2 Releases

Data Acquisition System(s)

Settings of the Slow Data Acquisition System (Frequency: 1 Hz)
Only used for pressure record of filling procedure

Settings of the Fast Data Acquisition System:
Frequency: 1 kHz Duration: 32 kSamples Duration: 65.536 s
Pre-Trigger: 30 % Recorded time interval: -19.7 ... 45.9 s
Trigger: Channel A5 (Enter Window 0.08 ... 4.9 V) OR Channel B1 (enter Window 2 ... 9 V)

Tab. 2: Channel-settings of the fast Data Acquisition System

Chan -nel	Sen- sor	Type	Ser.- Nr.	Range	Sensitivity	Filter	Range Data Acq. [V]	Remarks
A1	P1	Kulite ITQ-100	109	0-35 bar	3.5 bar/V	none	-0.1...4.9	
A3	T1	NiCr-Ni (d = 0.3)	-		10 K/V	none	-0.1...4.9	
A4	T2	NiCr-Ni (d = 0.3)	-		10 K/V	none	-0.1...4.9	
A5	F	Althen	123	0-2 kN.	0.2 kN/V	none	-0.1...9.9	
A6	W	MT-IND 429	-	0-150 kg	15 kg/V	none	-0.1...9.9	
A7	T3	NiCr-Ni (d = 0.3)	-		10 K/V	none	-0.1...4.9	
A8	C1	MK FTC300	513	0-100%H2	10%H2/V	none	-0.1...9.9	
B1	T4	NiCr-Ni (d = 0.3)	-		10 K/V	none	-0.1...4.9	
B2	C2	MK FTC300	514	0-100%H2	10%H2/V	none	-0.1...9.9	
B3	T5	NiCr-Ni (d = 0.3)	-		10 K/V	none	-0.1...4.9	
B4	C1	MK FTC300	515	0-100%H2	10%H2/V	none	-0.1...9.9	
B8	TRG	Trigger		TTL↗	-	none	-1...9	

Experimental Conditions

Tab. 3: Initial conditions of the DisCha-Experiments

			Ambience			Vessel		
Exp.- Nr.	Date [DD/MM/YY]	Start Time [hh/mm/ss]	$T_{amb.}$ [K]	$P_{amb.}$ [bar]	RH [%]	T_0 [K]	P_0* [bar]	Remarks (e.g.: H2 or N2, Wind,...)

*relative Pressure

Repositories

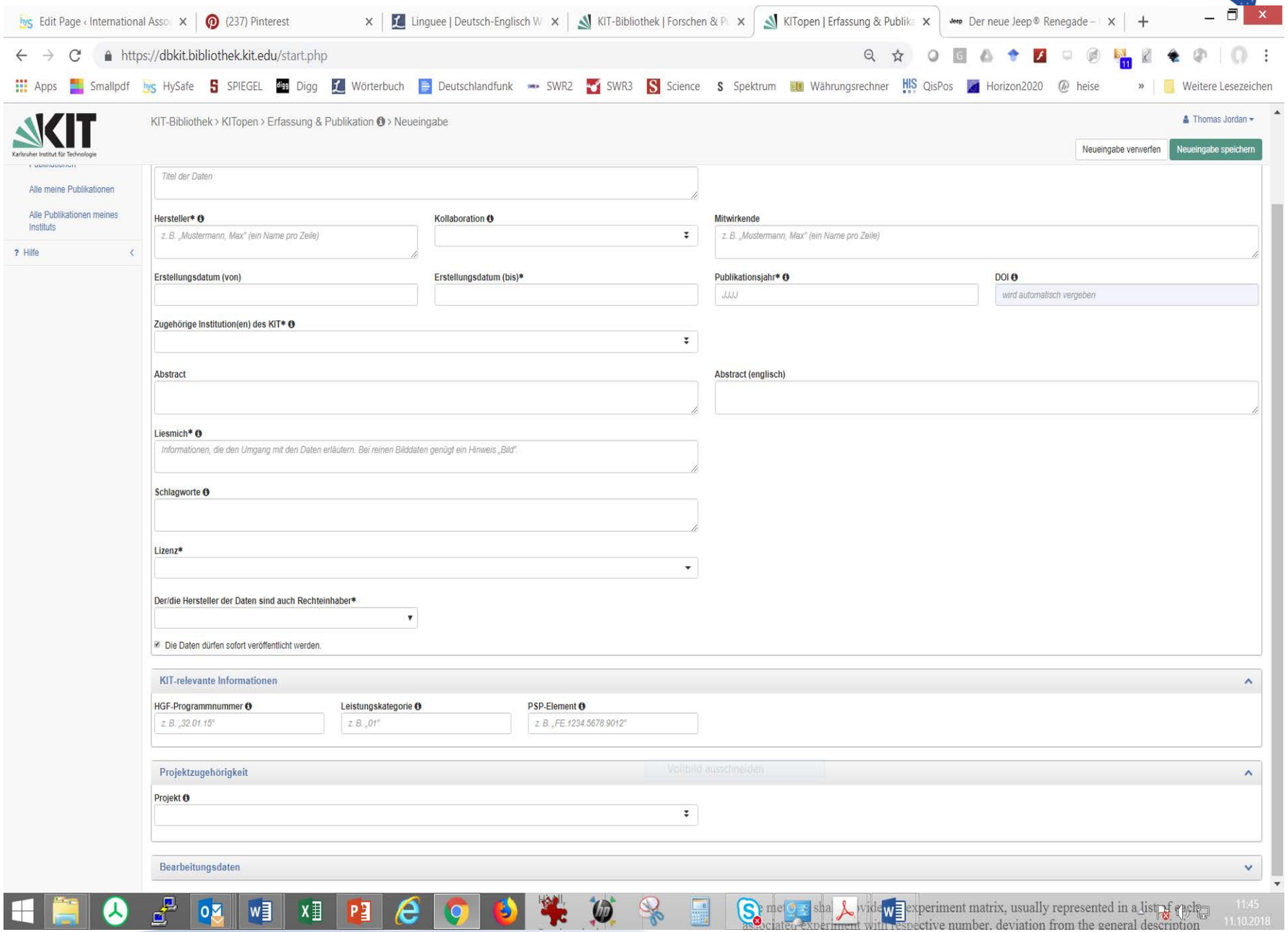
RADAR services for 25 years and the estimated 2 TB storage:
https://www.radar-projekt.org/display/RE/2016/05/09/Updated+price+information

25 x 500 Euro = 12500 Euro net
+ per 1 Gigabyte published data
2000 GB x 6,37 = 12740 Euro net

Total: ***25240 Euro*** net

KITopen services are *free* (initially limited to 10 years)
https://www.bibliothek.kit.edu/cms/english/kitopen.php

Data Input Interface for KITopen



Nomination of Data Management Team

- KIT: T. Jordan
- Pro-Science: A. Friedrich
- HSL: ?
- INERIS: ?
- WP2: E. Vyazmina
- WP3: A. Venetsanos
- WP6: D. Cirrone

Original extended experimental program for…

WP3 – Release & Mixing

WP4 – Ignition

WP5 – Combustion

WP/ Exp. Nr.	Phenomena/ Name	Issue addressed/ Objective	To be investigated	Variation of	Range of variables	n of variations	Partner/ Test facility
WP3 Release (experiments set italic are in reserve because of budgetary constraints)							
E3.1	**Small Scale Multi-phase Release**	Discharge Coefficients of Pressurized or LH2 Releases	pressure changes in bulk vessel temperature changes in a jet mass flow rate inertia (thrust), weight BOS images, laser diagnostics of jet principle structure, potential wall attachment/ impingement	Initial pressure Initial temperature Nozzle shape and cross-sectional area Extraction point (high/gaseous-low/liquid & middle)	0-200 bar (sub-critical & supercritical) 25-200K	4 4 4 3	KIT/ HYKA-H8(He) DISCHA-facility in Test chamber V = 2.867 dm³
E3.2	***Multi-phase High Pressure Release***	*Charcterisation of Pressurised LH2 releases using characteristic pipe diameters* *Scale up of E3.1 wrt inventory, release rates & p*		*Pressure, temperature, release type (length and diameter, orientation, thrust, discharge coefficient*	*0-1000 bar? (or highest pressure possible)*	*t.b.d.*	*HSL/ Suitable vessel required/system required*
E3.3	***Mid-Scale Multi-phase Release***	*LH2 jets/near field cloud dispersion*	*flash rate, momentum, velocity (Temperature pressure and concentration measurements in the near field from 0 to 1m), Cloud dispersion : temperature et concentration measurements (field instrumentation ~10 m)*	*orifice size , pressure*	*5/15 mm ; 0-10bar*	*3 x 3*	*INERIS/ 2 m3 vessel + 20 m line (1"ID)+discharge valve+calibrated orifice*
E3.4	**Pool of LH2**	Evaporation a spill of LH2 1 m2	evaporation rate, cold gas mixing, O2 entrainment BOS imaging temperature profile in a gas concentr. profile in a gas	Material of the ground Initial temperature	solid-liquid-porous 77-300K	3 3	KIT/ HYKA-H110(N2)
E3.5	**Rainout Tests**	LH2 Spray evaporation/ Pool formation	evaporation rate, pool formation		release height release up/down/horizont.	3 3	HSL/ Pool facility

WP/ Exp. Nr.	Phenomena/ Name	Issue addressed/ Objective	To be investigated	Variation of	Range of variables	n of variations	Partner/ Test facility
WP4 Ignition (experiments set italic are in reserve because of budgetary constraints)							
E4.1	**General ignition**	fundamental ignition parameters (MIE, AIT)	influence of the adiabatic mixing temperature on the standard ignition parameters	Concentration/temp	4 to 75% H2, -100°C to ambient (adiabatic mixing)	10 concentrations/temp	INERIS/ Available mixing nozzle
E4.2	**Electrostatic ignition in cold jet**	Pressurized LH2 jet	Electrostatic measurements Auto-ignition mechanism BOS images of the jet H2 concentration profile	Initial pressure Initial temperature Nozzle diameter	0-200 bar 33-200K		KIT/ HYKA-A1 "Paul Coupe"-Facility
E4.3	**Electrostatic ignition in cold plume**	Large scale cold cloud (combination with E3.5)	Electrostatic measurements Auto-ignition mechanism BOS images of the plumes H2 concentration profile			6	HSL/ same as 3.5
E4.4	**Ignition above pool**	a spill of LH2 1 m2	ignition position BOS imaging temperature profile in a gas	Material of the ground Initial temperature	solid-liquid-porous 77-300K		KIT/ HYKA-H110 same as E3.4
E4.5	**Condensed phase ignition**	Ignition of LH2/LOX/solid oxygen mixtures	Composition, energy and types of ignition source	Produce under idealised conditions to understand sensitivity and conditions for ignition.			HSL/ Blast test facility
E4.6	***Diffusion ignition of CcH2***	*Pressure limits for spontaneous ignition*	*Influence of temperature pipe diameter, length, orifice shape*	*Initial p, T; pipe diameter, length, orifice shape, position of rupture membrane*			*KIT or HSL*

WP/ Exp. Nr.	Phenomena/ Name	Issue addressed/ Objective	To be investigated	Variation of	Range of variables	n of variations	Partner/ Test facility
WP5 Combustion (experiments set italic are in reserve because of budgetary constraints)							
E5.1	**Jet Fire**	Pressure and heat radiation effects	Effects of variations on heat flux and dosis, temperature, max pressure and rise rate	Mass LH2 / initial pressure	0-200 g/ 0-200 bar	3	KIT/ DISCHA in HYKA-V220
			Measured with	Nozzle diameter	1-4 mm	3	Q160 or H110
			High speed video, BOS, pressure and radiation probes (bolometers)	Ignition location	0-2m	5	(similar E3.1)
				Ignition delay times	0-1s	4	
E5.2	**Flame acceleration and**	H2-air mixture in	Critical conditions for FA	H2 concentration	H2 concentration		KIT/ HYKA-H110
	DDT at cryogenic temperatures	obstructed tube 50 mm id	Critical conditions for DDT	Initial temperature	50-200K		or HYKA-Q160
			Flame dynamics	Initial pressure	1-5 bar		
			Schlieren images				
			Pressure measurements				
		H2-air mixture in congested tube 0.7m id		Initial temperature	H2 concentration		
E5.3	**Flame propagation over a spill of LH2**	3x9 m2 floor	Flame dynamics (video), Pressure measurements, Temperature measurements, BOS images	Initial temperature, Evaporation rate (derived in E3.4)	33-300		KIT/ HYKA-H110 (same as E3.4 and E4.4)
E5.4	***BLEVE***	*LH2*	*Max radius of fireball*	*Mass LH2*	*0-100 g*		*KIT/ HYKA-V220*
			Max. time of fireball	*ignition delay*	*0-2 s*		*or HYKA-V3*
			Dynamics of fireball	*Initial pressure*	*1-10 bar*		
			Pressure outside				
E5.5	**Flame propagation in obstructed /confined cold cloud**	FA and DDT with real geometrical constraints	Flame dynamics (video), Pressure measurements, Temperature measurements, BOS images	Congestion, confinement, inventory, ambient conditions	tbd	tbd	HSL