CERN

WP 3: Fire propagation and its limitation

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Sub work packages/topics

- WP 3.1 Air management systems
- WP 3.2 Reference design fires
- WP 3.3 Smoke extraction optimization
- WP 3.4 Filter policies w.r.t. RP

WP 3.1 Air management systems

- Input received from
  - DESY
    - HERA
    - XFEL
  - ESS
  - FNAL
    - LNBF
    - ILC
- CERN input
  - Accelerator complex
  - Large-scale experiments
  - Beam line facilities (ISOLDE, MEDICIS, etc.)

WP 3.1 Air management systems

Normal air management accelerator tunnel configurations

- CERN
  - Proton Synchrotron PS – transversal + longitudinal
  - Super Proton Synchrotron SPS - longitudinal
  - Large Hadron Collider LHC - longitudinal
- DESY
  - HERA - longitudinal
  - XFEL - longitudinal
- ESS - longitudinal
- FNAL
  - LNBF – dedicated smoke extraction system
  - ILC

WP 3.1 Air management systems

DESY – XFEL Smoke extraction

- Surface buildings:
  - *And the heat vent areas outlined in DIN 18230-1 are equal to or greater than 5% of the total floor space of the section*
- Experimental hall
  - *A mechanical smoke extraction system will be provided.*
  - *Mechanical smoke extraction triggered by fire detection?* 🇩🇪 ✓ 🇬🇧 ✗
- Linear accelerator tunnel (planned)
  - *To be installed at the start of the equipment installation phase*
  - *Smoke compartments ≈ 600 m, 23,000 $m^3 \cdot h^{-1}$*
  - *Max. smoke generation rate 17,640 $m^3 \cdot h^{-1}$ x 1.3 (30% ambient air)*
  - *Secured functionality: min. 50 minutes at 600ºC*
  - *Automatic triggering by smoke detection; manual triggering etc.*
- Fan out tunnel (beam lines); partially
  - Longitudinal smoke extraction, or,
  - Mechanical smoke extraction, depending on fire load density

Security and Workplace Safety Concepts for the Construction, Installation and Operation of the XFEL Research Facility, STUVA e.V., 2005

WP 3.1 Air management systems

DESY – XFEL Smoke extraction

Whole tunnel is used
for longitudinal smoke extraction;
In both directions!

Separation wall along
escape and rescue route

Security and Workplace Safety Concepts for the Construction, Installation and Operation of the XFEL Research Facility, STUVA e.V., 2005

WP 3.1 Air management systems

ESS

"Ventilation systems should be operated in such way as to limit the potential release of radio nuclides and their operation should be compatible with fire protection requirements."

1. Operation: 0.5 air changes per hour
2. Flush mode: 2 air changes per hour
3. Maintenance: up to 2 air changes per hour
4. Fire incident mode: stop supply units, keep extraction running

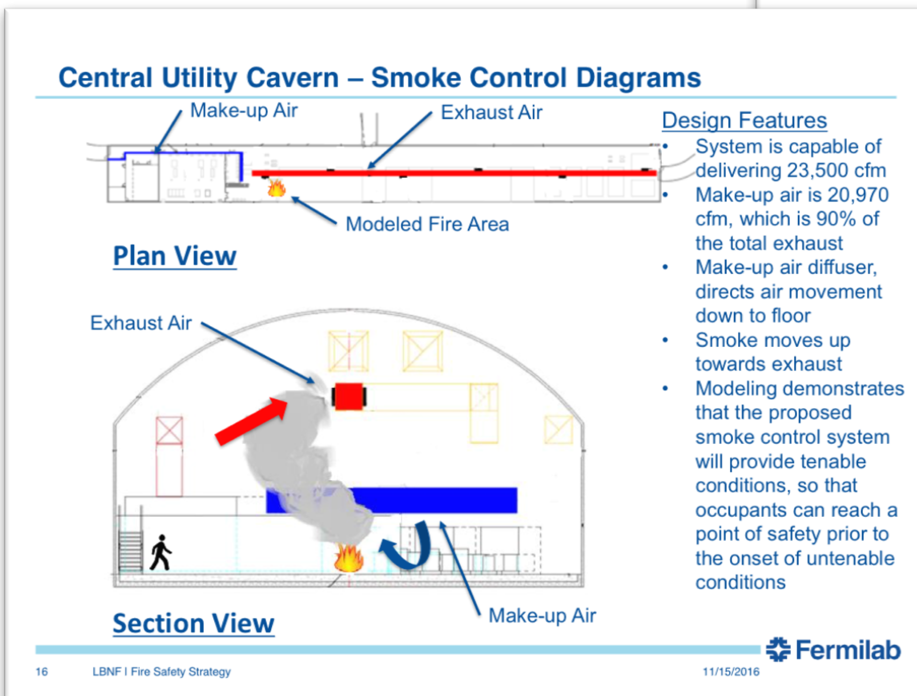
- Modes 1 and 2 must preserve negative pressure level of about 60 Pa w.r.t. the ambient
- Modes 3 is not constrained by dynamic confinement requirements
- Mode 4 could lead to higher pressure difference

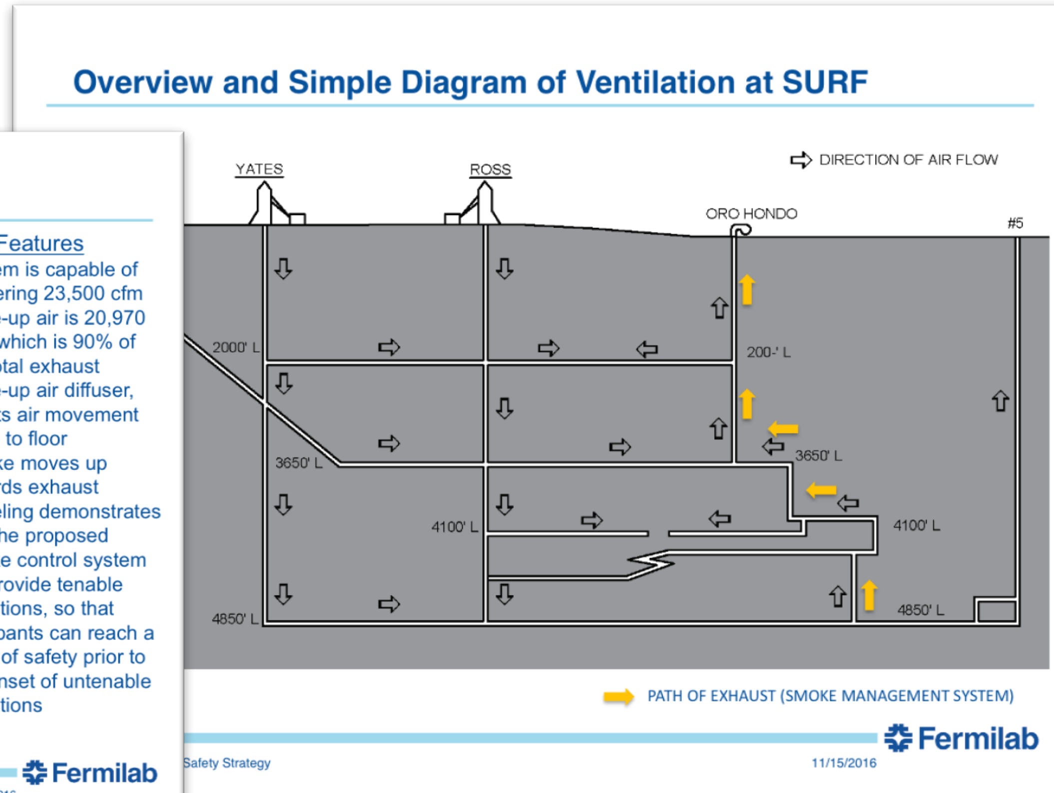
Activation of sprinkler system: does it impact the dynamic confinement?

ESS-0001051, Protection against Fire and Explosion, March 04, 2013
ESS-0039122, DM--SD-TBSIDDG01- System Description G01 HVAC, June 13, 2016

WP 3.1 Air management systems

FNAL – LNBF: real smoke extraction





J. Priest and J. Niehoff, Fire Safety Strategy for LBNF Project at SURF Presentation to the City of Lead AHJ, November 2016
ARUP, South Dakota Science and Technology Authority, A/E Services for Building, Site & Infrastructure Design in Support of the LBNF Far Site Conventional Facilities, Cavern Smoke Control Report, September, 2016

WP 3.2 Reference design fires

- Input
  - CHRISTIFIRE & Tristan's PhD work
  - Electrical cabinet tests (PRISME, etc.)
  - Reverse engineering CEA CDI cabinet data
  - LTH
    - Hi-LHC scenarios
    - Fire testing (cables, polyethylene etc.)
  - DESY cable fire report, XFEL safety concept
  - CERN fire reports

WP 3.2 Reference design fires

- Geometry depending
- Material depending
- Fuel vs. ventilation controlled scenarios
- Based on heat release rate (HRR)
- Pre-scribed HRR vs. more reality approach
- Suitability for accelerator and large-scale experiment facilities

WP 3.2 Reference design fires

Electrical cabinets

Open configuration:

- Peak HRR up to 1.6 MW
- Durations > 60 min
- Energy released ≈ 1.2 GJ/cab.

Closed config.:

- Peak HRR up to 0.6 MW
- Energy released up to 0.6 MJ/cab.

Table 3
Total energy released, initial mass of contents of fire cabinet, total mass loss, and effective heat of combustion in cabinet fire experiments

Experiment	Total energy (MJ)	Initial mass (kg)	Total mass loss (kg)	Total mass loss (%)	Effective heat of combustion (MJ/kg)
1	442[a]	66.5[b]	22.0	33	19.6[c]
2A		70.7	0.4		
2B		70.4	0.2		
2C	270	70.7	23.6	33	11.4
3	288	66.4	14.6	22	19.7
4	655	61.60	34.76	56	18.8
5	27	30.40	3.03	10	8.9
6A	[illegible]	91.05	0.56	1	5.4
6B	707	90.49	38.69	43	18.3
7	57.1	5.84	3.53	60	16.2
8	40.8	5.77	3.48	60	11.7
9	47.8	5.92	3.43	58	13.9
10	40.0	5.94	3.41	57	11.7

Half-closed (1–2C) / Closed (4–6B)

J. M. Chavez. An experimental investigation of internally ignited fires in nuclear power plant control cabinets, Part 1: Cabinet effects tests, NUREG/CR-4527/1, SAND86-0336. Technical report, Sandia National Laboratories, 1987.
J Mangs, J Paananen, O Keski-Rahkonen, Calorimetric fire experiments on electronic cabinets, Fire Safety Journal, Volume 38, Issue 2, 2003, Pages 165-186, ISSN 0379-7112, http://dx.doi.org/10.1016/S0379-7112(02)00055-3.
W. Plumecocq, M. Coutin, S. Melis, L. Rigollet, Characterization of closed-doors electrical cabinet fires in compartments, Fire Safety Journal, Volume 46, Issue 5, 2011, Pages 243-253, ISSN 0379-7112, http://dx.doi.org/10.1016/j.firesaf.2011.02.006.

CERN: cabinets at large-scale experiments are partially protected

EDMS 880054, MiniMax fire extinguishing system in ATLAS Experiment, May 2008

XFEL: all cabinets supplied with fire detection and inert gas ext. system

Security and Workplace Safety Concepts for the Construction, Installation and Operation of the XFEL Research Facility, STUVA e.V., 2005

WP 3.2 Reference design fires

DESY – XFEL Fire load density calculations

Initial fire load in XTL is about 87.5 kg/m.
Scaling of fire load w.r.t. a U2-type subway train (Frankfurt, Germany):

- Length 23m
- Heat of combustion approx. 22.53 MJ/kg; 88 GJ total
- Maximum smoke release rate 19 m^3/s after 15 minutes (3,419 kg)

$$\text{Example: XTL at cross-section 0 m} = \frac{87.5\text{kg/m} \times 19\text{m}^3/\text{s}}{3419\text{ kg}} = 0.49\ \text{m}^3/(\text{s} \times \text{m})$$

Cross-section of tunnel structure at [m]	Total amount of polymer in cable compartment, racks 1–7 approx. [kg/m]	Fire load[1)] approx. [MJ/m]	Fire load per 10 m of tunnel length[2)] approx. [MJ]	Smoke generation rate[3)] approx. [m³/(s x m)]	Smoke generation rate per 10 m of tunnel length approx. [m³/s]
1	2	3	4	5	6
XTL 0 m	87.5	1971	19,710	0.49	4.90

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WP 3.2 Reference design fires

DESY – XFEL Fire load density calculations

Stand: 08.04.2005

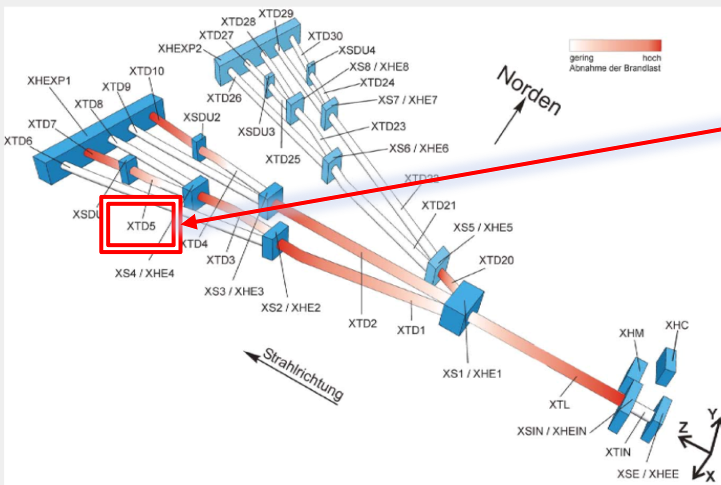

Abb. 8: Lage der größeren Brandlasten in den Tunneln XTL, XTD4 und XTD10 sowie XTD5 und XTD7

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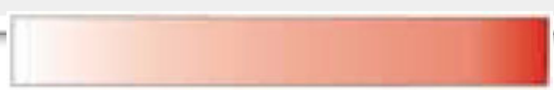

Fire load density

Bauwerk Querschnitt des Tunnels bei [m]
1
XTL 0 m
XTL 100 m
XTL 200 m
XTL 300 m
XTL 400 m
XTL 500 m
XTL 600 m
XTL 700 m
XTL 800 m
XTL 900 m
XTL 1000 m
XTL 1100 m
XTL 1200 m
XTL 1300 m
XTL 1400 m
XTL 1500 m
XTL 1600 m
XTL 1700 m
XTL 1800 m
XTL 1900 m
XTL 2000 m
XTD1 0 m
XTD1 250 m
XTD1 450 m
XTD2 0 m
XTD2 250 m
XTD2 550 m
XTD3 0 m
XTD3 50 m
XTD3 220 m
XTD4 0 m

Stand: 08.04.2005

Bauwerk Querschnitt des Tunnels bei [m]	Gesamte Polymer-menge in Kabelkammer Pritschen 1-7 ca. .[kg/m]	Brandlast[1] ca. . [MJ/m]	Brandlast auf 10 m Tunnellänge[2] ca. [MJ]	Rauch-menge[3] ca. [m³/(s x m)]	Rauchmenge auf 10 m Tunnel-länge ca. [m³/s]
1	2	3	4	5	6
XTD4 50 m	14	315	3.150	0,08	0,80
XTD4 250 m	34	766	7.660	0,19	1,90
XTD5 0 m	14	315	3.150	0,08	0,80
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
XTD5 180 m	34	766	7.660	0,19	1,90
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
XTD6 200 m	14	315	3.150	0,08	0,80
XTD6 600 m	14	315	3.150	0,08	0,80
[illegible]	[illegible]	[illegible]	7.660	0,19	1,90
[illegible]	34	[illegible]	7.660	0,19	1,90
XTD7 100 m	34	766	7.660	0,19	1,90
[illegible]	[illegible]	315	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	315	[illegible]	[illegible]	[illegible]
XTD8 350 m	14	315	3.150	0,08	0,80
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
XTD9 350 m	14	315	3.150	0,08	0,80
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,90
[illegible]	[illegible]	766	7.660	[illegible]	1,90
XTD10 150 m	34	766	7.660	0,19	1,90

XTD5 180m
Fire load: 766 MJ/m
Smoke generation rate per 10m: 1.9 m³/s

1) berechnet mit einem Heizwert von 22,53 MJ/kg (U2-Fahrzeug, Frankfurt); Beispiel XTL bei Querschnitt 0 m = 87,5 kg/m x 22,53 MJ/kg = 1.971 MJ/m

2) Zum Vergleich: Brandlast des 23 m langen U2-Triebfahrzeuges, Frankfurt: ca. 87.700 MJ, d.h. auf 10 m Länge ca. 38.000 MJ

3) berechnet mit einer Rauchmenge von 19 m³/s (maximaler Wert nach 15 Minuten Branddauer) bezogen auf 3419 kg brennbarer Masse (23 m langes U2-Fahrzeug, Frankfurt);

Beispiel: XTL bei Querschnitt 0 m = $\frac{87{,}5\ kg/m \times 19\ m^3/s}{3.419\ kg}$ = 0,49 m³/(s x m)

Tabelle 9: Auswertung der Brandlasten in den Tunnelbauwerken

4.4.5 Dump-Schächte XSDU1 und XSDU2

Die Dump-Schächte haben keinen Zugang von der Geländeoberfläche und werden daher bei der brandschutztechnischen Bewertung als aufgeweitete Tunnelquerschnitte betrachtet. Daher gelten auch bei den Dump-Schächten die brandschutztechnischen Grundforderungen gemäß Kapitel 3.5.2.

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WP 3.3 Smoke extraction optimization

- Oriol’s work on simplified tunnel modeling
- Proposal based on FDS by Saverio
- Tristan looking into implementing Latin Hypercube sampling on CERN resources
- High performance computing resources to be allocated

Does this item makes sense on CDR level?

O. Rios, Usability of simplified tunnel modelling with MineFirePro+ for CERN’s accelerator complex, ongoing, 2017 to present
EDMS 1396658, A smoke extraction system for FCC - Feasibility study, July 2014
Kathrin Grewolls, Probabilistic Modelling of Sensitivity in Fire Simulations, Dissertation, University of Central Lancashire, July 2013
FDSgeogen, http://www.fz-juelich.de/ias/jsc/EN/Research/ModellingSimulation/CivilSecurityTraffic/FireDynamics/Software/_node.html

WP 3.4 Filter policies w.r.t. RP

- DESY
  - No principal filter use; continuous RP monitoring system PANDORA in place at outlets
  - Automatic shutdown of air handling units based on thresholds
- ESS
  - Type 7 + HEPA filters for air supply and extraction units
- CERN
  - continuous RP monitoring system RAMSES in place
  - Beam line laboratories (ISOLDE, MEDICIS)

CERN, EDMS 1711815, AIR MANAGEMENT OF CERN ACCELERATORS AND EXPERIMENTS, July 28, 2016 (under approval)
DESY, F. Saretzki, S. Mohr, Contribution FCC collaboration interim report, December 2016
ESS, ESS-0039122, DM--SD-TBSIDDG01- System Description G01 HVAC, June 13, 2016

WP 3.4 Filter policies w.r.t. RP

CT-Analyst, e.g. for the assessment of filter choice / accidents
https://www.nrl.navy.mil/lcp/ct-analyst
http://www.bbk.bund.de/DE/TopThema/TT_2012/Software_CT-Analyst_Hamburg.html

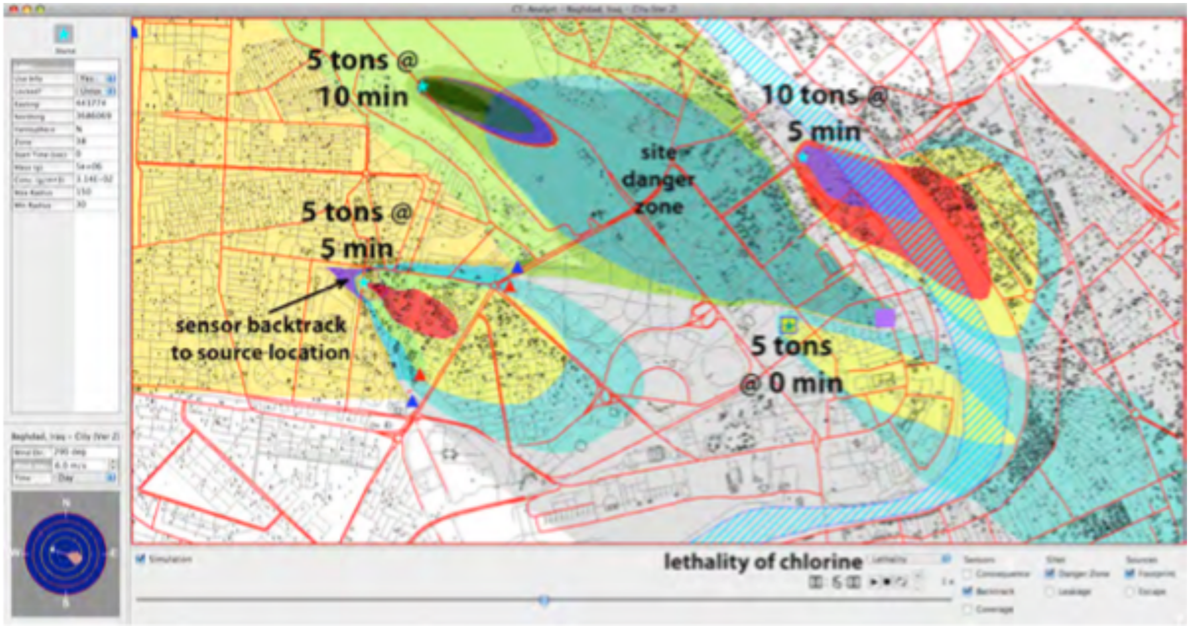
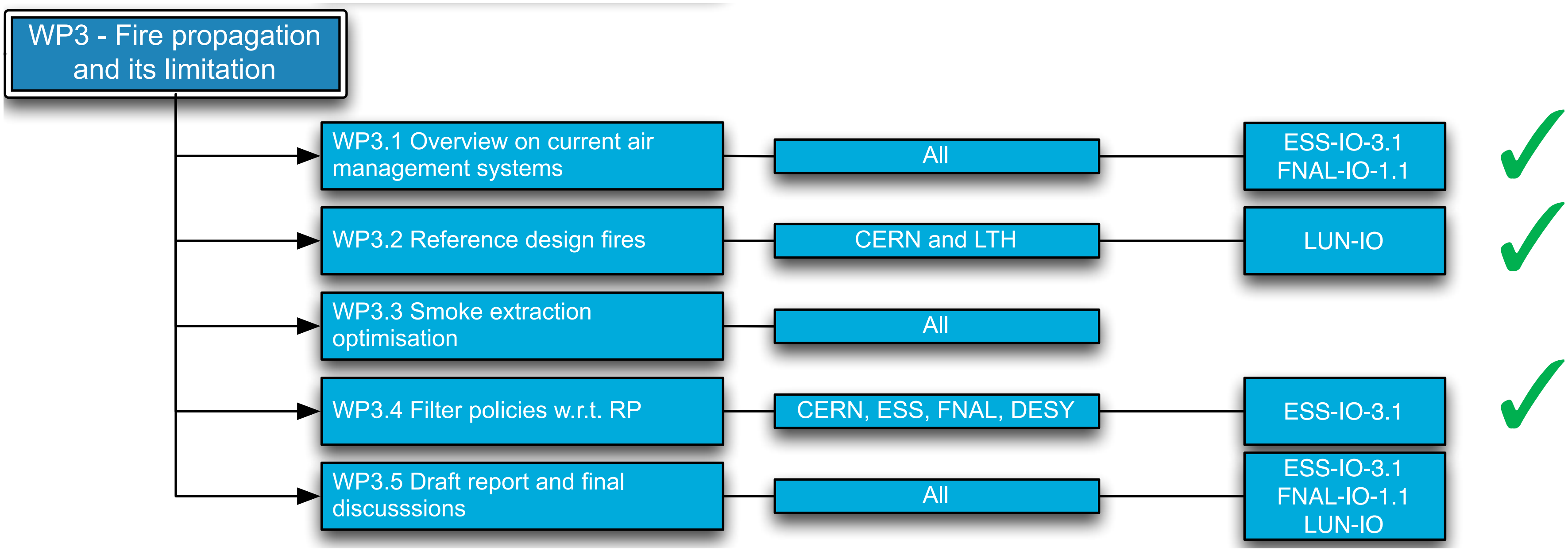


Figure: The entire CT-Analyst GUI display predicting lethality for a scenario involving four separate chlorine releases in downtown Baghdad. […] Computation for this composite display takes about 0.1 second.*

* J. Boris et al., Fast and accurate prediction of windborne contaminant plumes for civil defense in cities, The Fifth International Symposium on Computational Wind Engineering (CWE2010), Chapel Hill, North Carolina, USA May 23-27, 2010

Where are we?



FNAL: Technical note, LTH: Document, ESS: Report

Discussions!

http://minimumble.thebookofbiff.com/2012/03/07/58-collision/

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