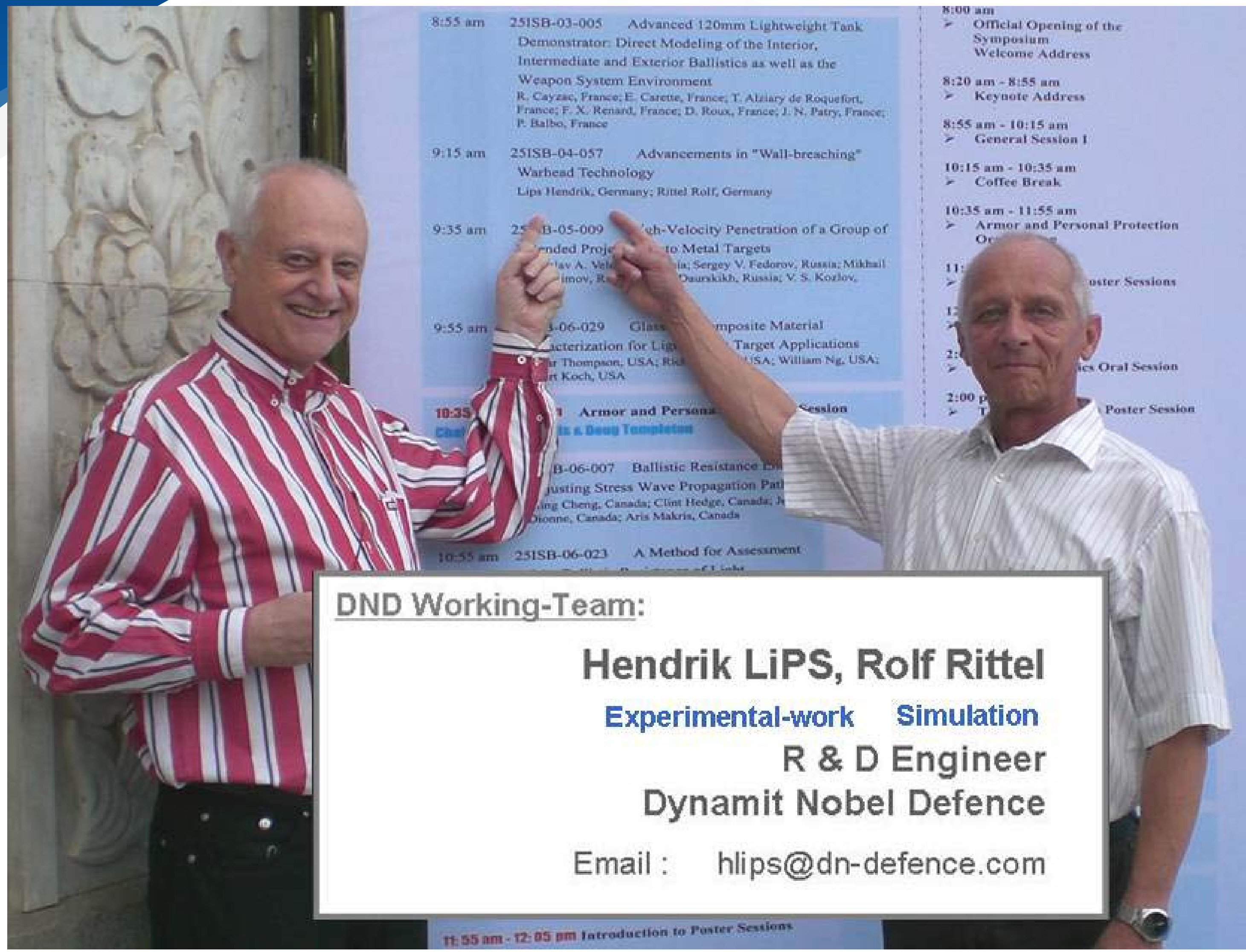
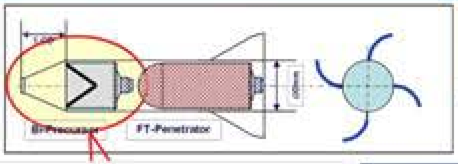
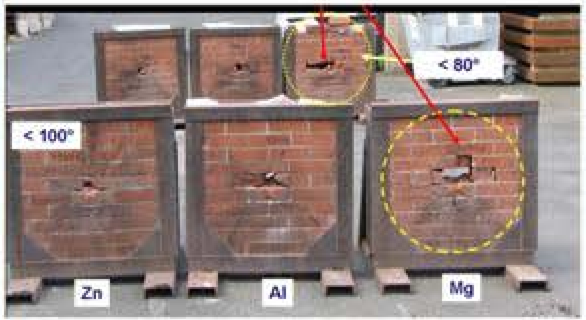
SIBEX for ASW

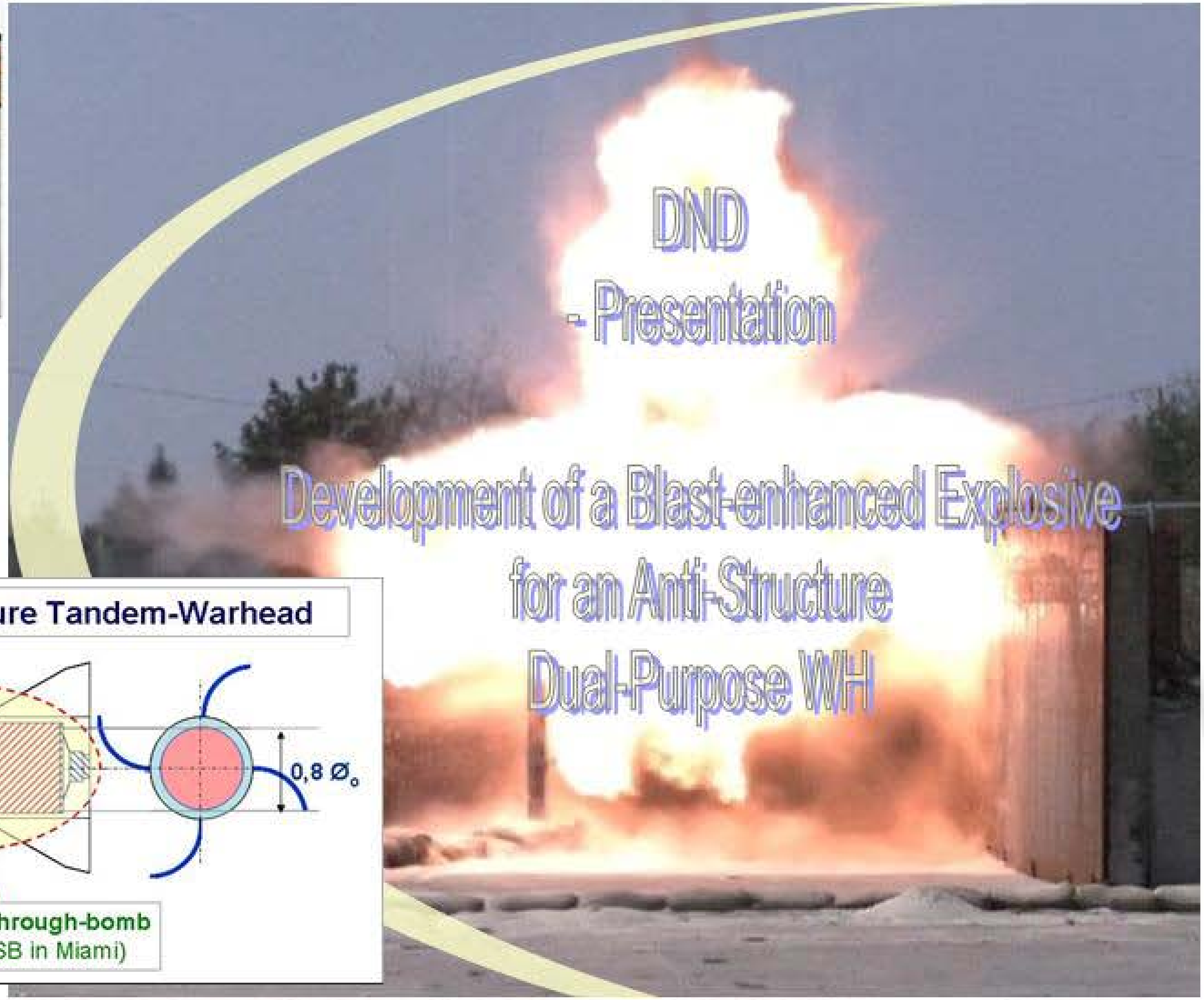


FTB for Tandem anti-structure WH

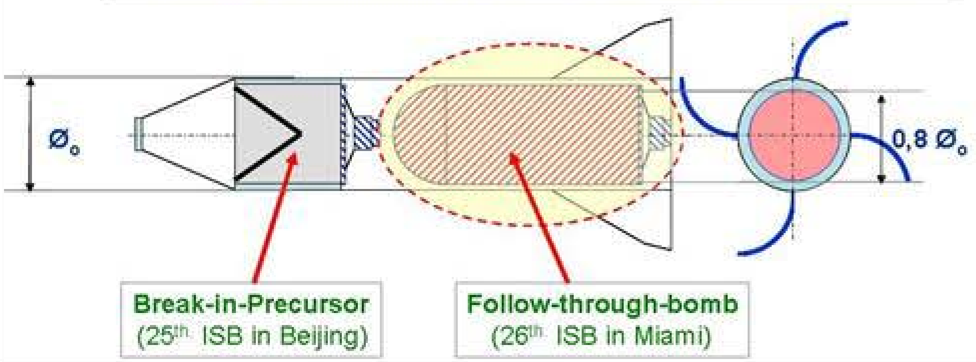


Hole diameters of Break-in-Precursor in Brick-walls





Dual-purpose Anti-Structure Tandem-Warhead



Outline of presentation:

- Background: FTB for Tandem anti-structure WH
- Objective: selection of a dual-purpose SIBEX
- Requirements on SIBEX
- Characterization: 4 diff. SIBEX types
- Approach: Down-selection test-matrix
- SIBEX Screening-steps:
  - Level-1: free-field & open-corner tests
  - Level-2: single-room tests & simulations
  - Level-3: multi-chamber Bunker trials & simulations
- Ranking & Selection
- Conclusions & Future work

SIBEX for ASW

Characterization of 4 diff. SIBEX types

SIBEX Explosive Types

Solid SIBEX Explosives

SIBEX-I
- 80% RDX
- 20% HTPB

SIBEX-II
- 55% HMX
- 45% HTPB+Al

SIBEX-III
- 55% HMX+AP
- 45% HTPB+Al

Liquid SIBEX Explosives

SIBEX-IV
- 60% Al
- 40% IPN (liquid) +RDX

Charge Design

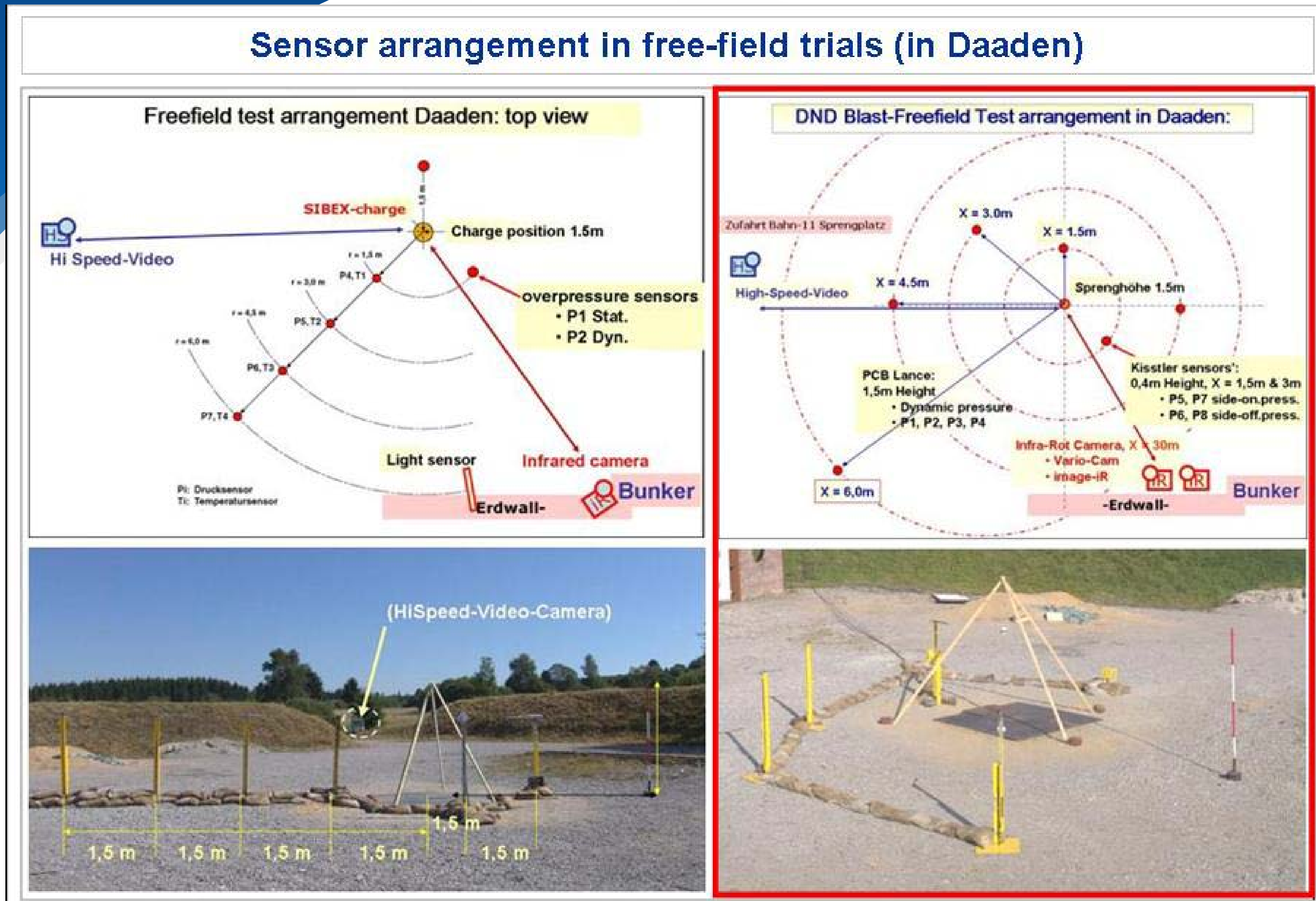
Volumen	L/D	Masse
450 cc	2,5	~ 750 g
900 cc	1,2	~1500 g
1900 cc	2,4	~3000 g

Charge design for SIBEX selection trials:

- 450 cc charge: structures & simulation trials
- 450 cc charge: closed single-chamber trials
- 900 cc charge: free field & open-corner trials
- 1900 cc charge: enclosure multi-room trials

Summary of detonation & thermodynamic properties of SIBEX

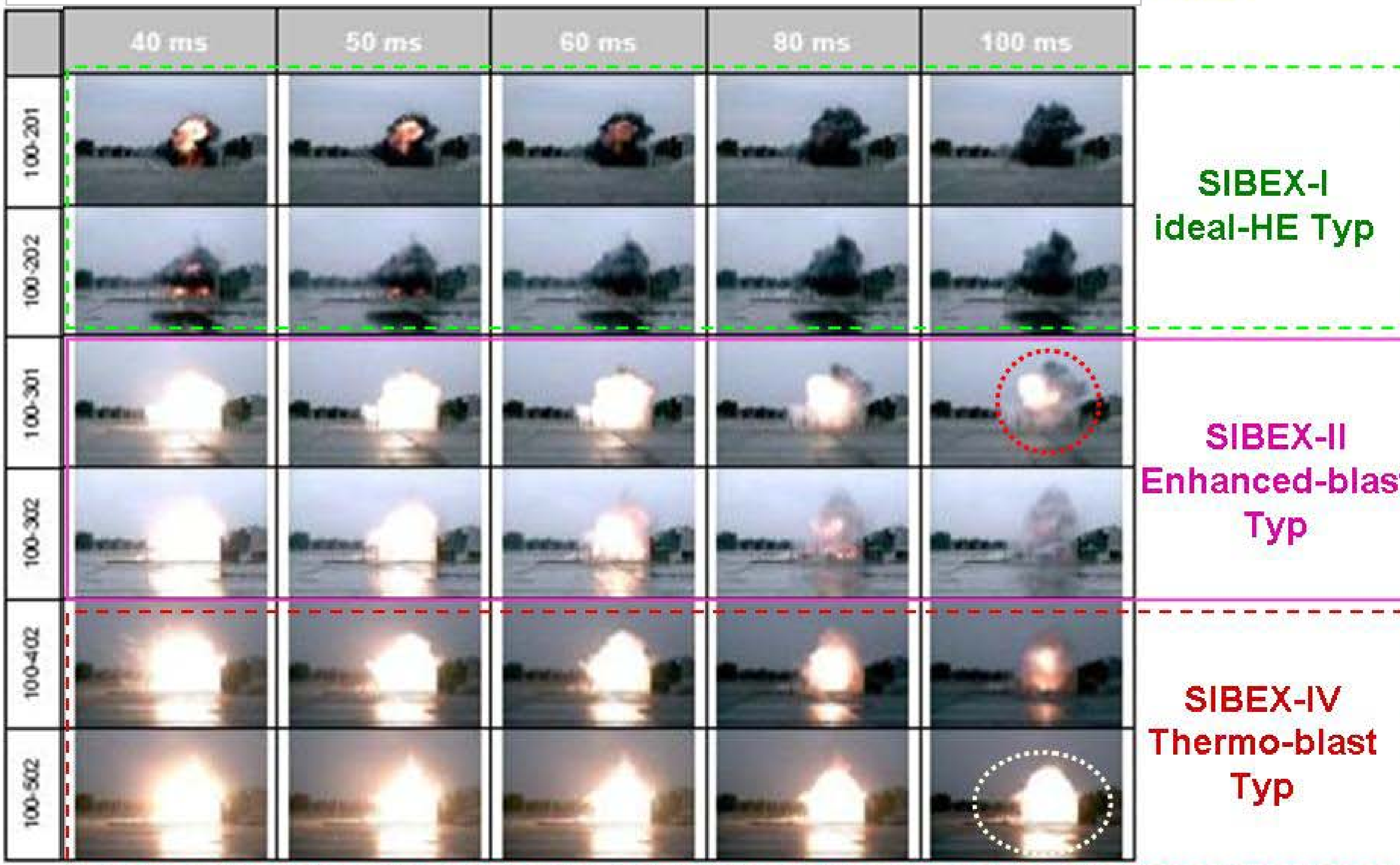
Detonation & thermodynamic properties of SIBEX Formulations				
SIBEX type	SIBEX I	SIBEX II	SIBEX III	SIBEX IV
Explosive characterization	ideal Explosive	less ideal Explosive	Non ideal Explosive	No Explosive
Density [g/cm³]	1,66	1,82	1,8	1,4
Detonation velocity (m/s)	8380	7530	5700	-/-
Detonation pressure P_{C-J} (kbar)	**300**	**255**	**114**	-/-
Detonation Temperature [K]	3750	5000	4840	4150
Heat of formation [kcal/kg]	- **60**	- **40**	- **190**	- **210**


Sensor arrangement in free-field trials (in Daaden)
Freefield test arrangement Daaden: top view
SIBEX-charge
Charge position 1.5m
Hi Speed-Video
P4, T1
P5, T2
P6, T3
P7, T4
overpressure sensors
• P1 Stat.
• P2 Dyn.
Light sensor
Infrared camera
Bunker
Erdwall-
Pi: Drucksensor
Ti: Temperatursensor
DND Blast-Freefield Test arrangement in Daaden:
Zufahrt Bahn-11 Sprengplatz
X = 3.0m
X = 1.5m
X = 4.5m
High-Speed-Video
Sprenghöhe 1.5m
PCB Lance:
1,5m Height
• Dynamic pressure
• P1, P2, P3, P4
Kisstler sensors':
0,4m Height, X = 1,5m & 3m
• P5, P7 side-on.press.
• P6, P8 side-off.press.
Infra-Rot Camera, X ≈ 30m
• Vario-Cam
• image-iR
X = 6,0m
Bunker
-Erdwall-
(HiSpeed-Video-Camera)
1,5 m
1,5 m
1,5 m
1,5 m
1,5 m
1,5 m

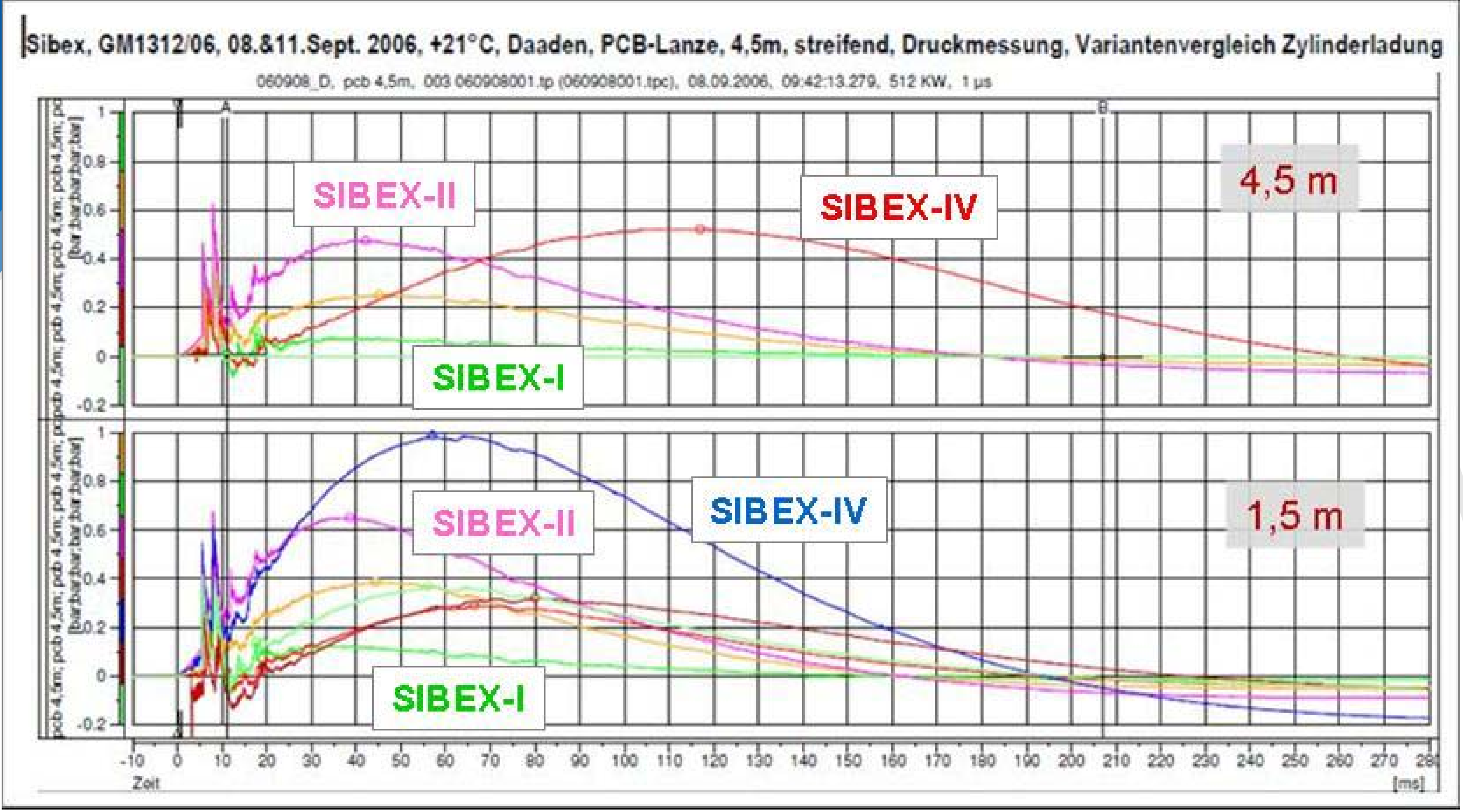
SIBEX for ASW

post combustion [reaction-time in ms]

tests



Free-field "Blast" results of 4 diff. SIBEX types



Test facilities for Characterization of SIBEX-Formulations

Open-Space Trials
(DND-Daaden & WTD-91 Sprakel)

Free-field

surface reflexion:
- 0.4m (with)
- 1,5m (without)

Open-Corner

Multi-reflexions:
- surface &
- side-walls

Enclosure Trials
(Test facilities WTD-91)

Urban-Module "Hüntel"

Closed-in-door-rooms + corridor (8x 50m^3)

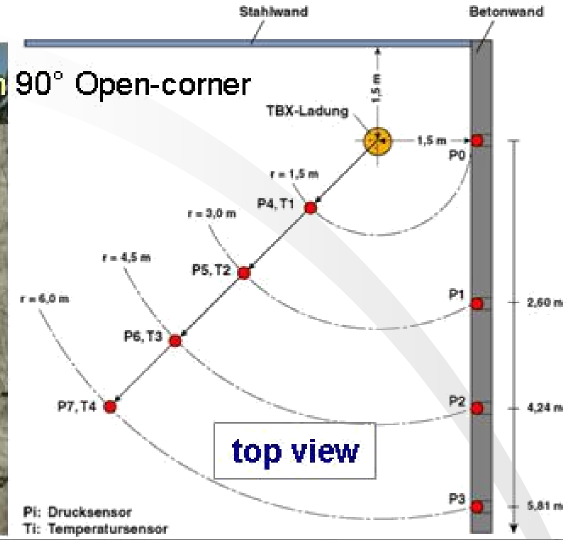
Bunker "Ladeburg"

(Multi-room Bunker (70m^3-rooms)

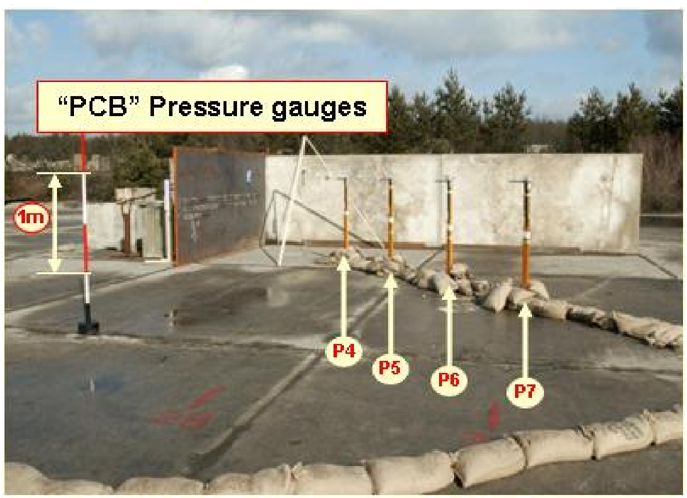
Open-corner "Sprakel"

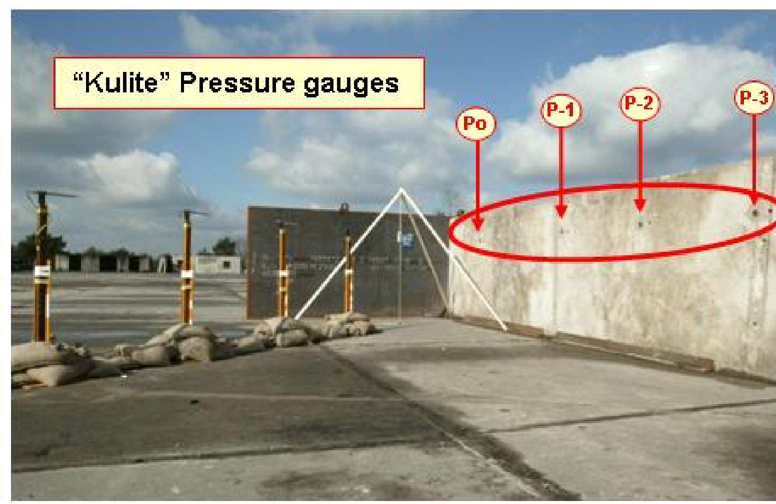
Urban-Module "Hüntel"

Bunker "Ladeburg"



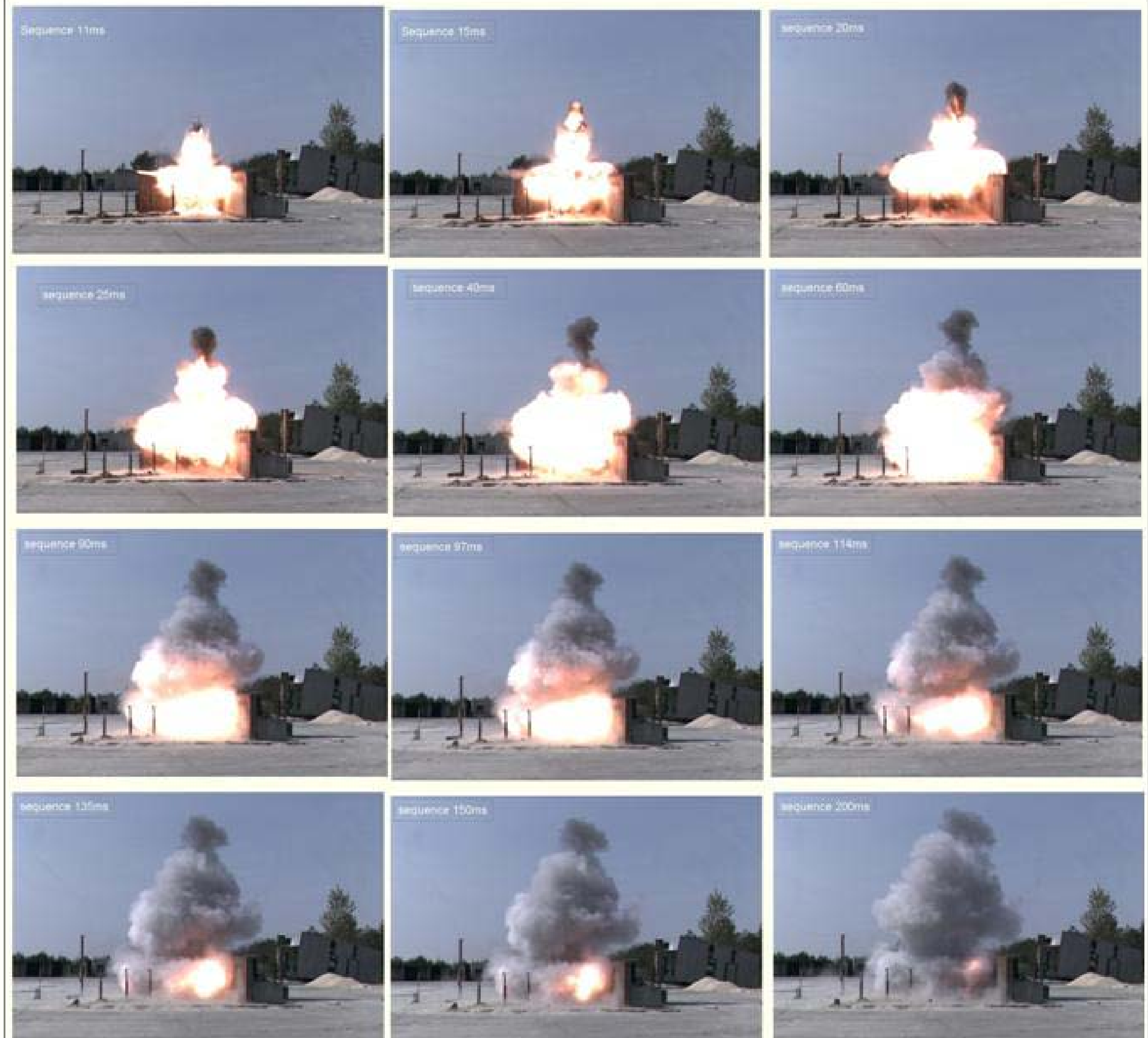
Test arrangement WTD-91 Free-field open-corner test assembly with solid-barriers





SIBEX for ASW

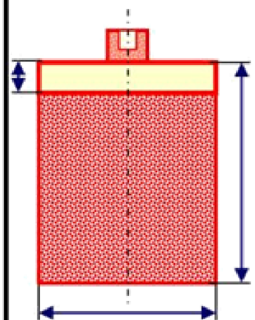
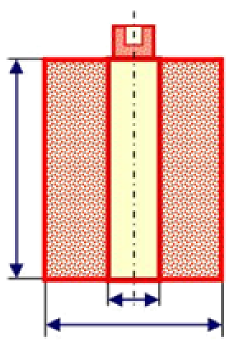
Trial SIBEX-II; Free-field Open-corner Explosion

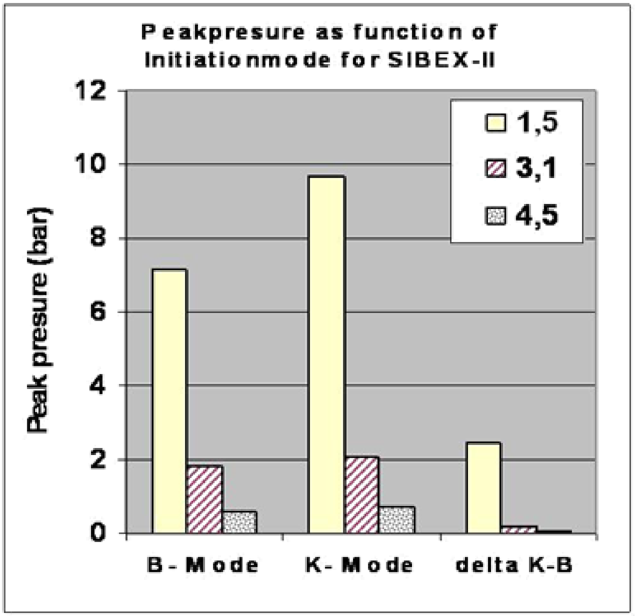


SIBEX-II
K-Mode
HS-video
(10-200 µs)

SIBEX for ASW

Peak pressure vs. distances as function of Initiation mode for SIBEX-II

Distance [m]	Initiation Mode	B-Mode	K-Mode	delta
				
		Peak pressure [bar]		delta
1,5	UU	7,188	9,667	2,479
3	UU	1,814	2,037	0,223
4,5	UU	0,604	0,694	0,091
6	UU	0,416	0,413	-0,003

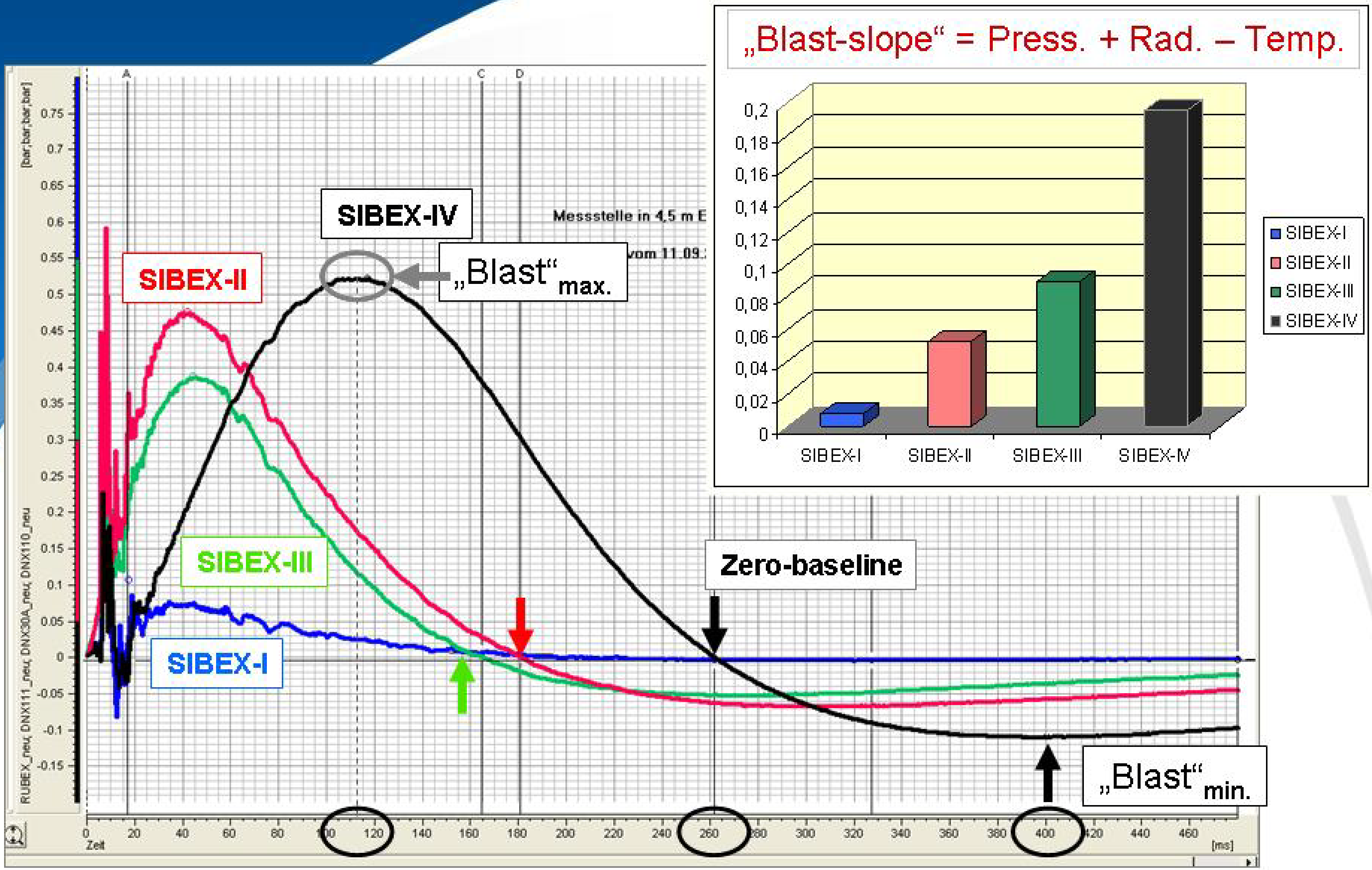


Conclusion: K-Mode gives 35% higher peak pressures at 1,5 m (at 3 m distance 12% higher PP)

free field open-corner tests: SIBEX-II vs. SIBEX-III

Trial with SIBEX-III (1.5 kg at 1,5 m height)	Trial with SIBEX-II (1.5 kg at 1,5 m height)

post combustion of particle cloud [reaction-time in ms]

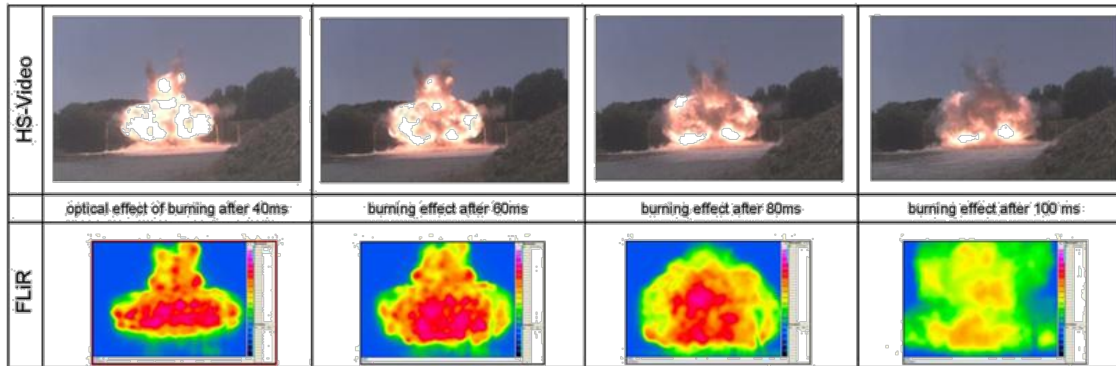

„Blast-slope“ = Press. + Rad. – Temp.
0,2
0,18
0,16
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
SIBEX-I
SIBEX-II
SIBEX-III
SIBEX-IV
SIBEX-IV
„Blast“max.
SIBEX-II
SIBEX-III
SIBEX-I
Zero-baseline
„Blast“min.
Messstelle in 4,5 m E
vom 11.09.
[bar;bar;bar;bar]
RUBEX_neu; DNX111_neu; DNX30A_neu; DNX110_neu
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
A
C
D
0
Zeit
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
[ms]

SIBEX for ASW

screening SIBEX formulations by FLiR in open field trials

results FLiR temperatures of SIBEX compositions

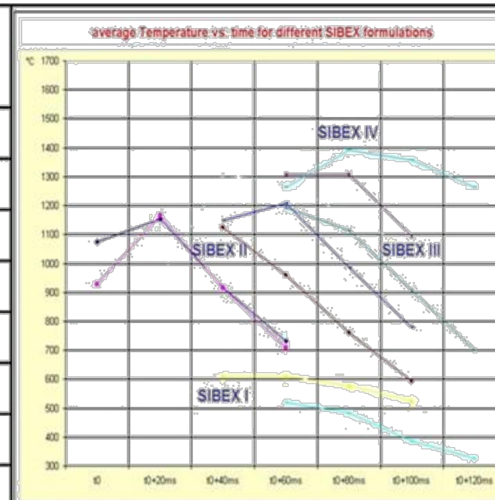
900cc SIBEX-II



optical effect of burning after 40ms | burning effect after 60ms | burning effect after 80ms | burning effect after 100 ms

infrared effect of burning at 40ms | Cloud expansion at 60 ms | Cloud expansion after 80 ms | Cloud expansion after 100 ms

SIBEX Typ	Initiation Mode	FLiR-Camera T max.	FLiR-Camera T mean
SIBEX I	OO	1147	792
	UU	/	/
SIBEX II	OO	1620	1309
	UU	1560	1123
SIBEX III	OO	1570	1192
	UU	1554	1210
SIBEX IV	OO	**1703**	**1391**
	UU	1585	1308

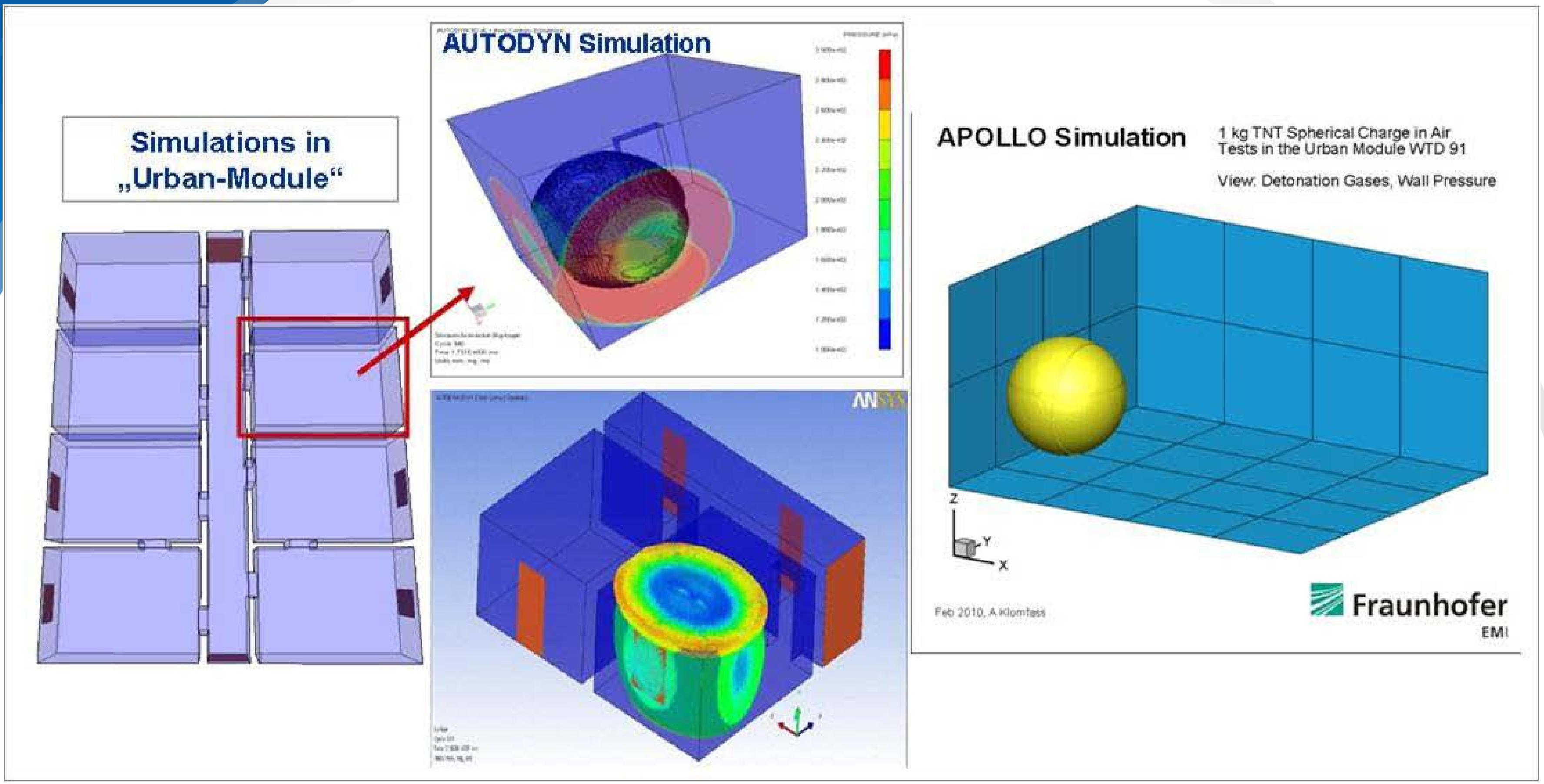


Conclusion:

- SIBEX-IV gives highest combustion temperatures
- SIBEX-II & SIBEX-III have the same combustion temperatures

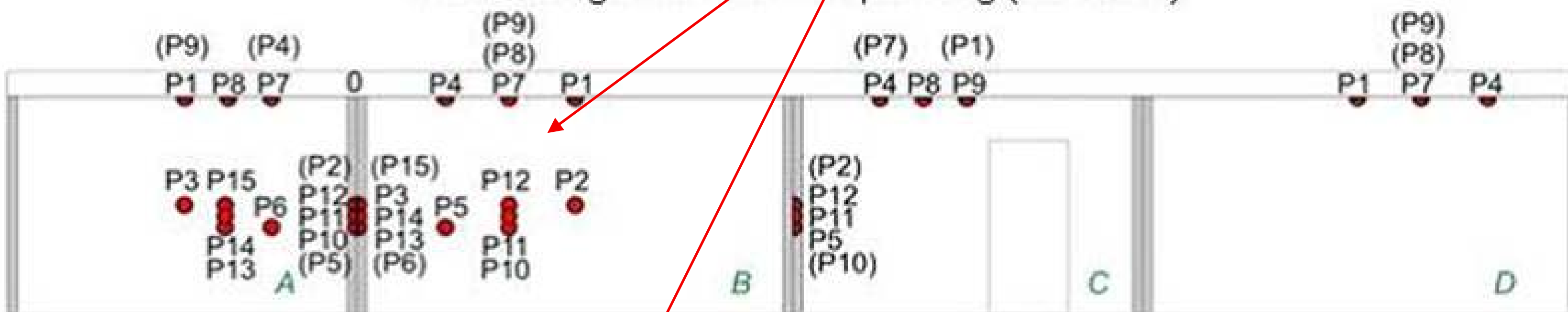
SIBEX Screening results in free-field tests

Formulation	SIBEX- I	SIBEX- II	SIBEX- III	SIBEX- IV
Combustion time	40 ms	100 ms	80 ms	180 ms
Mean temp. (FLiR)	792 °C	1309 °C	1192 °C	1391 °C
Peak pressure	11,7 bar	9,3 bar	7,8 bar	4,1 bar
"Blast"-Integral (?)	7 (?)	32 (?)	42 (?)	74 (?)
valuation	highest Peak-pressure			highest time-integral
first selection		second best	second best	
second selection		**Further screening in Bunker in-door tests**		


Simulations in „Urban-Module“
AUTODYN Simulation
APOLLO Simulation
1 kg TNT Spherical Charge in Air
Tests in the Urban Module WTD 91
View: Detonation Gases, Wall Pressure
Feb 2010, A.Klomfass
Fraunhofer
EMI

Urban-Module at WTD-91 proving ground in Meppen, Germany

"Hüntel" single room sensor planning (side-view)



Heat-flux & pressure gauges (room-view)

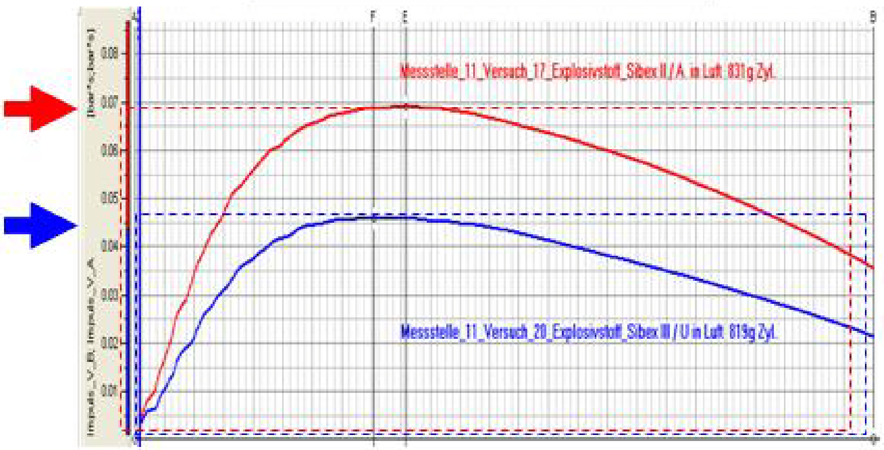
"Kulite" pressure gauges (top-view)

Test set-up in single room "Hüntel"

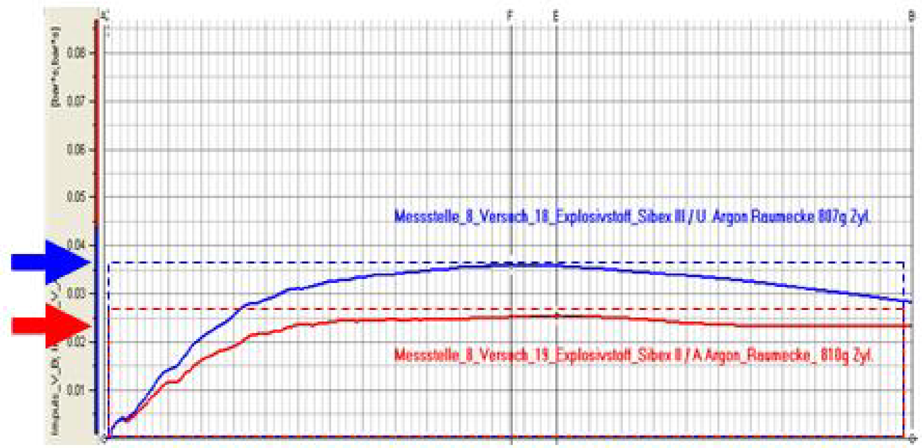
SIBEX charge — Charge fixture — Sensor arrangement

Comparison test results of single room trials of two SIBEX's in argon & air atmospherics

SIBEX -II & -III in Air



SIBEX -II & III in Argon



SIBEX II [HMX] vs. SIBEX III [AP] in Air

Test result:

SIBEX- II => 71,4 mbars

SIBEX- III => 55.4 mbars

Conclusion in Air :

is SIBEX-II 28% better as SIBEX III

SIBEX II [HMX] vs. SIBEX-III [AP] in Argon

Test result :

SIBEX- II => 21.2 mbars

SIBEX- III => 26,6 mbars

Conclusion in Argon :

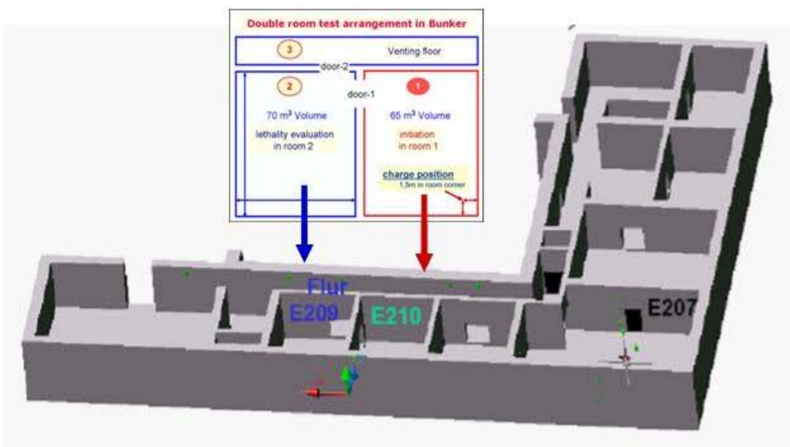
is SIBEX-III 25% better as SIBEX-II

Bunker „Ladeburg“ in Sprakel at WTD-91

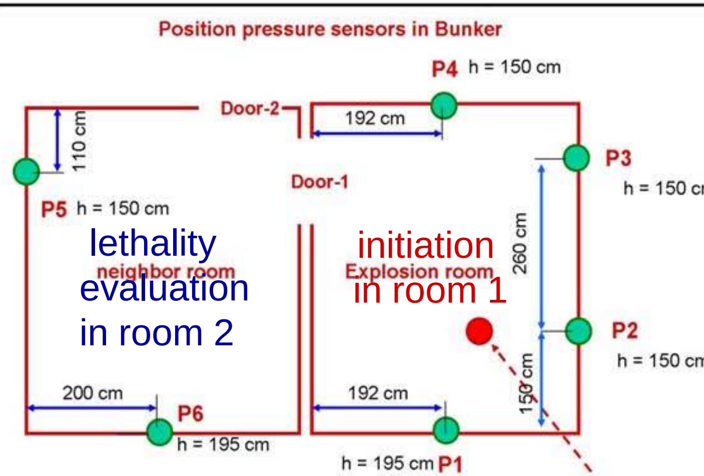
Air view bunker

WTD 91

Side view with bunker entrances

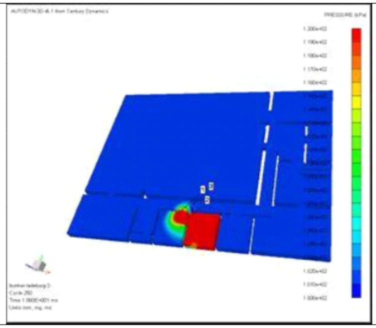
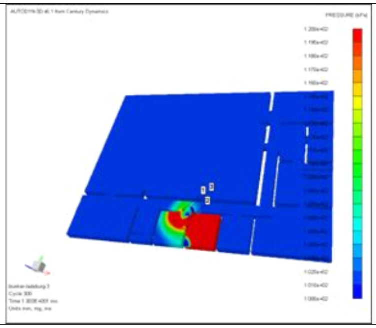
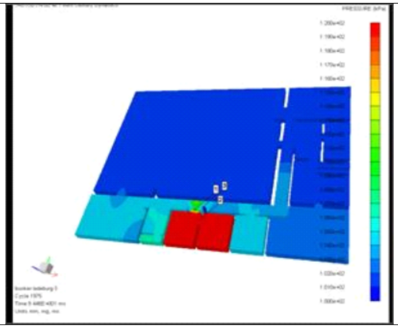
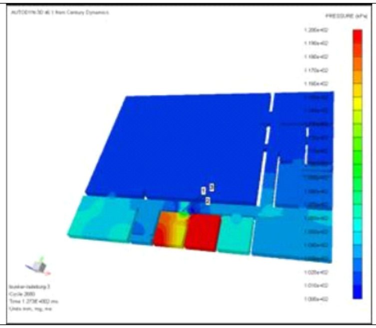
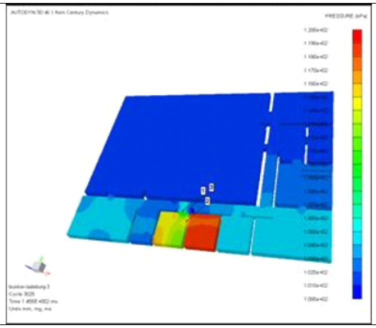
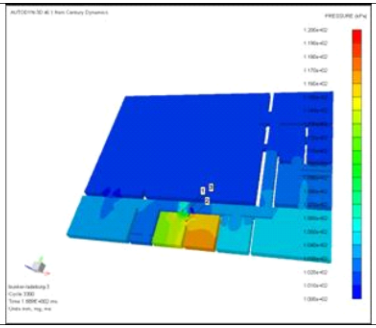


Room arrangement for modeling

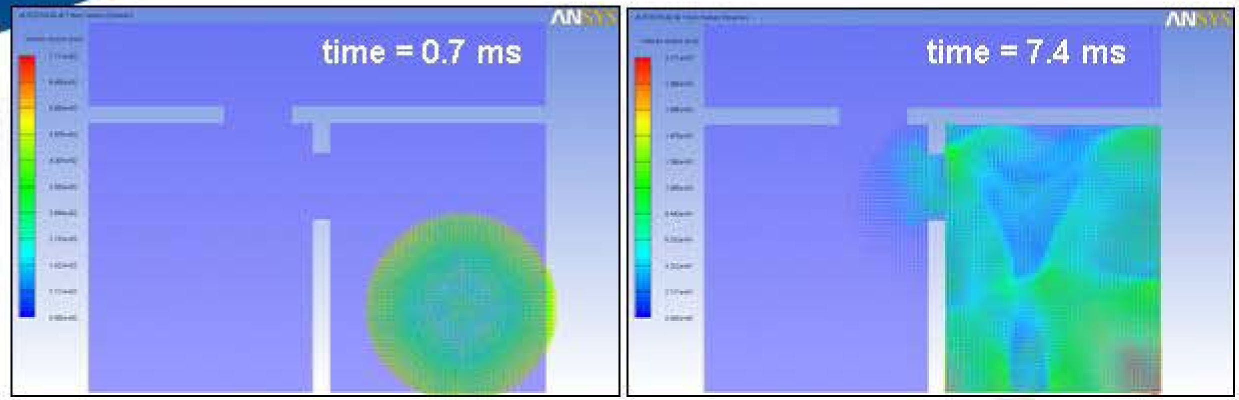


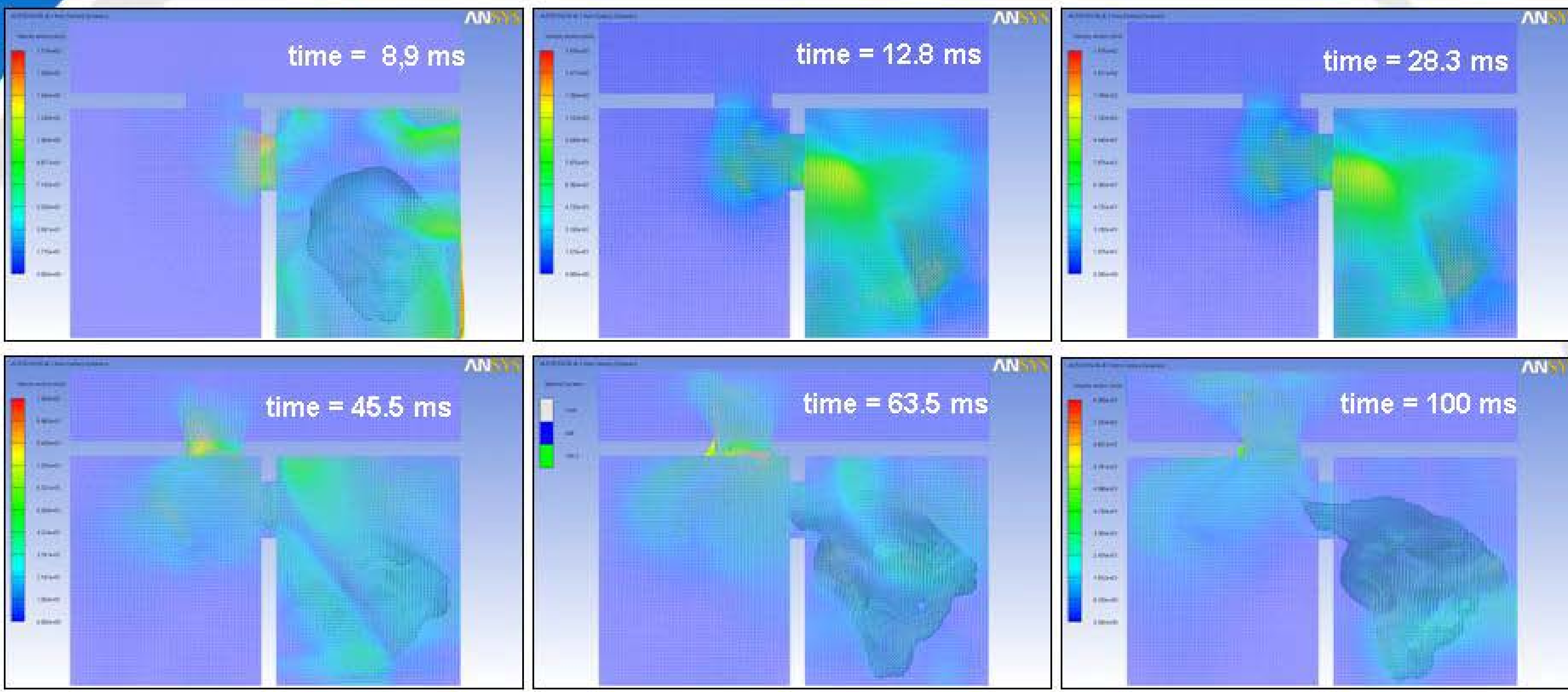
Locations pressure gauges

Modelling gas expansion in bunker „Ladeburg"
(for 1900cc SIBEX-I explosive charge)

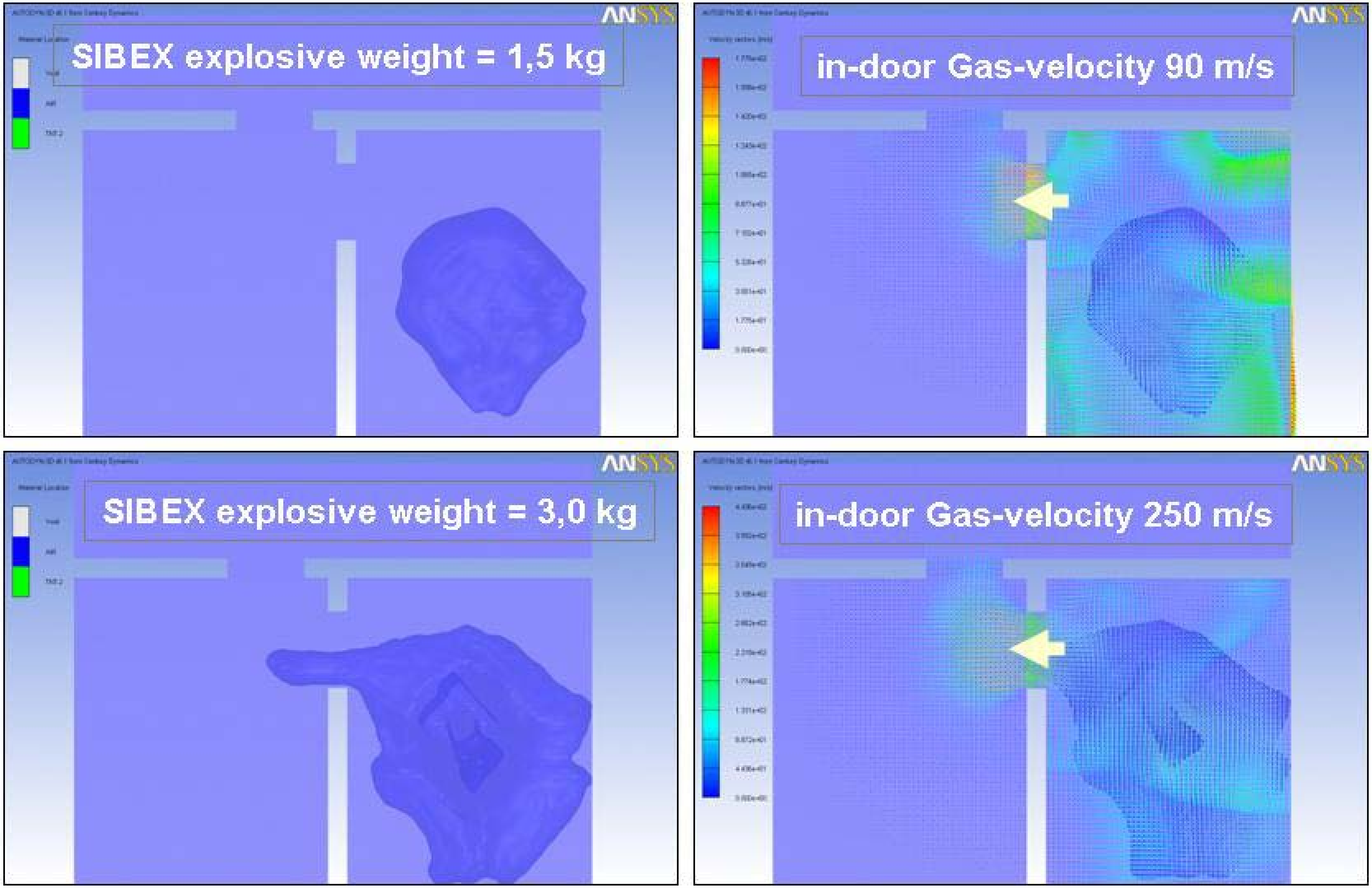
Gas expansion after 10ms	Gas expansion after 13ms	Gas expansion after 95ms
		
		
Gas expansion after 127ms	Gas expansion after 146ms	Gas expansion after 160ms

Particle-cloud driven by the shock-waves





in-door flow velocity from room-to-room: 1.5 kg vs. 3,0 kg



SIBEX for ASW

Ranking results in Bunker tests & SIBEX selection				
Formulation	SIBEX-II		SIBEX-III	
Reaction time	100 ms	1	80 ms	2
Peak pressure	9,3 bar	1	7,8 bar	2
Blast-Impulse	32 mbar.s	2	42 mbar.s	1
Ranking factor		**4**		**5**
valuation	the best		second best	
Selection	best Dual-purpose			

Summary & Conclusions:

- PCB pressure-gauges are suitable for characterization of post-combustion properties
- Valuable tool for Ranking & selection ("qualitatively")
- SIBEX-II is the best "Dual-purpose" formulation
- Modeling with "Autodyn" & "Apollo" gives a good impression about the "inert-fume" behavior

Future work:

- Integration of thermodynamic & chemical kinetics into the Simulation codes
- Investigate the measured PCB-parameters more "quantitatively" (separates -press. -radiation & temp.)

Impact & "man-holing" effect of 450cc Follow-through Blast-bomb

Detonation Break-in-Precursor in front of the Adobe-wall

Detonation FTB in Adobe-wall

Acknowledgements

the author wish to thank:

- **Dr. W. Kalz**, from the BWB
  for the financial support of the project
- **Mr. Fahl**, proving ground WTD-91 in Meppen
  providing the bunker test facilities.
- **Dr. Klomfass**, the Fraunhofer EMI
  for his 3D modeling with the "Apollo-code"

Thank You 4 Attention !

if you have any Questions ?
ask me now !