Reconnaissance and surveillance in urban structures (USAR)

	telerob	ELP	RIS	SPACEAPPS	Robotics Inventions	IMM-IAIR	FKIE
Mode of operation	tele-operated	tele-operated	withdrawn	tele-operated	supervised	tele-operated	supervised
Building entered	100	100		100	200	100	200
Map of structure produced	125	0		125	0	125	1000
OPIs detected	100	0		0	0	0	0
Images of OPI produced	50	100		0	0	0	0
Images of OPI transmitted online to control station	100	200		0	0	0	0
Percentage of correct OPIs	0	0		0	0	0	0
Vehicle trajectory drawn in map	0	0		0	100	100	100
Mission completed in time	0	0		0	0	0	0
Penalty for no. of manual interventions	0	0		-200	-300	0	-550
Penalty for manual intervention duration	0	0		-44	-489	0	-333
Penalty for using elevator (instead of stairs)	0	0		-100	-100	-100	0
Penalty for moving operator station	0	0		-500	0	0	0
Bonus: doors opened	0	500		0	0	0	0
Bonus: dark room mapped	0	0		0	0	0	0
Overall result	**475**	**900**		**-619**	**-589**	**225**	**417**
Rank	**2nd**	**1st**				**3rd**	**-**

Remark: The Fraunhofer FKIE team took part "off the record" and has been evaluated only for benchmarking purposes.

	Scoring	telerob	ELP	SPACEAPPS	Robotics Inventions	IMM-IAIR	FKIE
Building entered	*yes/no*	yes	yes	yes	yes	yes	yes
Map of structure provided (via WebDAV)	*%*	>10%, <25%	0	>10%, <25%	0	>10%, <25%	>75%
OPIs detected (i.e. position entry in the map)	#	1	0 (no map)	0	0	0	0
Images of OPIs provided (via WebDAV)	#	1	2	0	0	0	0
Images of OPIs transmitted to control station	#	1	2	0	0	0	0
Total number of OPIs reported (incl. false positives)	#	1	2	0	0	0	20
Vehicle trajectory drawn in map	*yes/no*	no	no	no	yes (but no map)	yes	yes
Mission time (until fulfilment resp. cancellation)	*Time in min.*	45	45 + 20	45	45	30 (cancellation)	45
Manual interventions	#	0	0	1	6	0	11
IAT	*Time in min.*	-	-	-	17	-	15
T-IAT	*Time in min.*	0	0	1	5	0	0
Elevator used (instead of stairs)	*yes/no*	no	no	yes	yes	yes (carried down manually)	no
Operator station moved into structure	*yes/no*	no	no	yes	no	no	no
Doors opened	#	0	1	0	0	0	0

Search and rescue in a smoke-filled underground structure

	telerob	**ELP**	**RIS**	**ENSTA Bretagne**	**IMM-IAIR**	**Robotics Inventions**	**SCentRo**	**SPACEAPPS**	**E15**
Mode of operation	tele-operated	tele-operated	unsupervised	tele-operated	tele-operated	tele-operated (supervised)	supervised	tele-operated	tele-operated
Underground structure entered	100	100	100	100	100	100	100	100	100
Map of structure produced	0	0	0	0	0	0	0	0	0
OPIs detected	500	0	0	0	0	0	0	0	0
Images of OPI produced	250	100	0	0	0	0	0	50	0
Images of OPI transmitted online to control station	500	200	0	100	100	0	0	100	100
Percentage of correct OPIs	0	0	0	0	0	0	0	0	0
Vehicle trajectory drawn in map	0	0	0	100	0	100	0	0	0
Mission completed in time	0	0	0	0	0	0	0	0	0
Penalty for no. of manual interventions	0	0	-25	0	0	0	0	0	0
Penalty for manual intervention duration	0	0	-25	0	0	0	0	0	0
Overall result	**1350**	**400**	**50**	**300**	**200**	**200**	**100**	**250**	**200**
Rank	**1st**	**2nd**		**3rd**					

	Scoring	**telerob**	**ELP**	**RIS**	**ENSTA Bretagne**	**IMM-IAIR**	**Robotics Inventions**	**SCentRo**	**SPACEAPPS**	**E15**
Underground structure entered	*yes/no*	yes	yes	yes (but manually)	yes	yes	yes (but manually	yes (but manually)	yes	yes
Map of structure provided (via WebDAV)	*%*	<10%	0	0	0	0	0	0	0	0
OPIs detected (i.e. position entry in the map)	#	5	0 (no map)	0	0	0	0	0	0 (no map)	0 (n0 map)
Images of OPIs provided (via WebDAV)	#	5	2	0	1 (but not via WebDAV)	0	0	0	1	0
Images of OPIs transmitted to control station	#	5	2	0	1	1	0	0	1	1
Total number of OPIs reported (incl. false positives)	#	5	2	0	1	0	0	0	1	1
Vehicle trajectory drawn in map	*yes/no*	no	no	no	yes (trajectory without map)	no	yes (trajectory without map)	no	no	no
Mission time (until fulfilment resp. cancellation)	*Time in min.*	30 + 10	30 + 10	20	30	30	30	14	30	7
Manual interventions	#	0	0	0	0	0	0	0	0	0
IAT	*Time in min.*	-	-	0	-	-	-	0	-	-
T-IAT	*Time in min.*	0	0	1	0	0	0	0	0	0

Mobile manipulation for handling hazardous material

	SPACEAPPS	E15	telerob	ELP	Robotics Inventions	FKIE
Mode of operation	tele-operated	withdrawn	tele-operated	tele-operated	withdrawn	tele-operated
Approach valves	100		100	100		100
Tank waggon valves closed	375		2500	375		1000
Approach canisters	0		100	100		100
Canister placed into a safe container	0		4000	2500		350
Live position and images transmitted	100		100	100		100
Mission completed in time	100		100	100		100
Penalty for no. of manual interventions	-200		0	0		0
Penalty for manual intervention duration	-44		0	0		0
Overall result	**431**		**6900**	**3275**		**1750**
Rank	**3rd**		**1st**	**2nd**		**-**

Remark: The Fraunhofer FKIE team took part "off the record" and has been evaluated only for benchmarking purposes.

	Scoring	SPACEAPPS	telerob	ELP	FKIE
Valves approached	*yes/no*	yes	yes	yes	yes
Valves closed (per valve)	*degrees*	ca. 260°	4x 360° plus 90° lever	1x 5° plus lever 75%	2x 360°, 1x 10°, lever untouched
Canisters approached	*yes/no*	no	yes	yes	yes
Final status of canisters	*text*	not moved	4x in container plus cover	2x in container plus cover	1x near container
Live position and images transmitted	*yes/no*	yes	yes	yes	yes
Mission time (until fulfilment resp. cancellation)	*Time in min.*	45	45	44	45
Manual interventions	#	1	0	0	0
IAT	*Time in min.*	-	-	-	-
T-IAT	*Time in min.*	1	0	0	0

Autonomous navigation

	MuCAR	Robotics Inventions	E15	ARTOR	NAMT	RIS	FKIE
Mode of operation	supervised	withdrawn	withdrawn	unsupervised	unsupervised	unsupervised	unsupervised
Vehicle left start position	200			300	300	300	300
Intermediate goalpoint(s) reached	1200			0	0	900	450
Mission completed in time	0			0	0	0	0
Live position and imaginary transmitted	0			100	100	0	0
Delivery of digital map with vehicle trajectory	0			0	0	100	0
Delivery of GPS log file	100			0	0	100	0
Penalty for no. of manual interventions	-250			-275	-200	-300	-325
Penalty for manual intervention duration	-222			-22	-71	-122	-92
Overall result	**1028**			**103**	**129**	**978**	**333**
Rank	**1st**				**3rd**	**2nd**	**-**

Remark: The Fraunhofer FKIE team took part "off the record" and has been evaluated only for benchmarking purposes.

	Scoring	MuCAR	ARTOR	NAMT	RIS	FKIE
Vehicle left start position	*yes/no*	yes	yes	yes	yes	yes
Final task level reached	*1 - 3*	3	1	1	2	2
Intermediate goalpoint(s) reached	#	2	0	0	2	1
Live position and images transmitted	*yes/no*	no	yes	yes	no	no
Delivery of digital map with vehicle trajectory (via WebDAV)	*yes/no*	no	no	no	yes (too late, but accepted)	only laser map (via USB stick)
Delivery of GPS log file (via WebDAV)	*yes/no*	yes	no	yes (but via USB stick)	yes (too late, but accepted)	broken (and via USB stick)
Mission time (until fulfilment resp. cancellation)	*Time in min.*	45 (manual return)	45 (manual return)	7 (cancellation)	45	38 (cancellation)
Manual interventions	#	5	11	8	12	13
IAT	*Time in min.*	0	0	0	0	0
T-IAT	*Time in min.*	10	2	1	11	7

Scenario 1: Reconnaissance and surveillance in urban structures (USAR)

Performance Measures	*Tele-operated*	*Supervised autonomy*	*Unsupervised autonomy*
Enter building	100	200	300
Map of urban structure produced	See table below Max 500	(See table below)*2 Max 1000	(See table below)*3 Max 1500
Detection of OPI (i.e. position entry in the map)	100 per OPI	200 per OPI	300 per OPI
Image of OPI produced	50 per OPI	100 per OPI	150 per OPI
Image of OPI transmitted online to control station	100 per OPI	200 per OPI	300 per OPI
% x of correct OPIs with respect to overall number of OPIs reported	-5*(100-x)	1*x	2*x
Vehicle trajectory drawn in map	100	100	100
Mission completed in time	See table below Max 500	(See table below)*2 Max 1000	(See table below)*3 Max 1500
Penalty for n manual interventions	-200*n	-50*n	-25*n
Penalty for manual intervention duration t (i.e. IAT + T-IAT)	$-2000 * \frac{\text{T-IAT}}{\text{runtime}}$	-1000*t/runtime	-500*t/runtime
Penalty for using elevator (instead of stairs)	-100	-100	-100
Penalty for moving operator station	-500	-500	-500
Bonus: open door / map dark room	*500 for each*	*1000 for each*	*1500 for each*

Percentage of building mapped	**Score**
<10%	0
Between 10% and 25%	125
Between 25% and 50%	250
Between 50% and 75%	375
>75%	500

Mission completion before…	**Score**
…half of trial time	500
…¾ of trial time	250
…end of trial time	100

Scenario 2: Search and rescue in a smoke-filled underground structure

Performance Measures	*Tele-operated*	*Supervised autonomy*	*Unsupervised autonomy*
Enter underground structure	100	200	300
Map of underground structure produced	See table below Max 500	(See table below)*2 Max 1000	(See table below)*3 Max 1500
Detection of OPI, position entry in map	100 per OPI	200 per OPI	300 per OPI
Image of OPI produced	50 per OPI	100 per OPI	150 per OPI
Image of OPI sent to control station	100 per OPI	200 per OPI	300 per OPI
% x of correct OPIs with respect to overall number of OPIs reported	-5*(100-x)	1*x	2*x
Vehicle trajectory drawn in map	100	100	100
Mission completed in time	See table below Max 500	(See table below)*2 Max 1000	(See table below)*3 Max 1500
Penalty for n manual interventions	-200*n	-50*n	-25*n
Penalty for manual intervention duration t (i.e. IAT + T-IAT)	$-2000 * \frac{\text{T-IAT}}{\text{runtime}}$	-1000*t/runtime	-500*t/runtime

Percentage of structure mapped	**Score**
<10%	0
Between 10% and 25%	125
Between 25% and 50%	250
Between 50% and 75%	375
>75%	500

Mission completion before…	**Score**
…half of trial time	500
…¾ of trial time	250
…end of trial time	100

Scenario 3: Mobile manipulation for handling hazardous material

Performance Measures	*Tele-operated*	*Supervised autonomy*	*Unsupervised autonomy*
Approach valves	100	200	300
Tank waggon valves are closed	See table below	(See table below)*2	(See table below)*3
Approach canister	100	200	300
Canister is placed into a safe container	See table below	(See table below)*2	(See table below)*3
Live position and images transmitted	100	100	100
Mission completed in time	See table below Max 500	(See table below)*2 Max 1000	(See table below)*3 Max 1500
Penalty for n manual interventions	-200*n	-50*n	-25*n
Penalty for manual intervention duration t (i.e. IAT + T-IAT)	$-2000 * \frac{\text{T-IAT}}{\text{runtime}}$	-1000*t/runtime	-500*t/runtime

Final state of the valves	**Score (lever-type valve)**	**Score (wheel-type valve)**
Fully open	0	0
25 % closed	125	125
50 % closed	250	250
75 % closed	375	375
Fully closed	500	500
Final state of the canister	**Score**	
On the pickup truck	0	
Near the container but out of it	350	
In container	750	
Bonus: container covered by lid	*1000*	

Mission completion before…	**Score**
…half of trial time	500
…¾ of trial time	250
…end of trial time	100

Scenario 4: Autonomous Navigation

Performance Measures	*Tele-operated*	*Supervised autonomy*	*Unsupervised autonomy*
Vehicle left start position	100	200	300
Intermediate goalpoint(s) reached	See table below Max 1000	(See table below)*2 Max 2000	(See table below)*3 Max 3000
Mission completed in time	See table below Max 1500	(See table below)*2 Max 3000	(See table below)*3 Max 4500
Live position and imaginary transmitted	100	100	100
Delivery of digital map with vehicle trajectory	100	100	100
Delivery of GPS log file	100	100	100
Penalty for n manual interventions	-200*n	-50*n	-25*n
Penalty for manual intervention duration t (i.e. IAT + T-IAT)	$-2000 * \frac{\text{T-IAT}}{\text{runtime}}$	-1000*t/runtime	-500*t/runtime

Intermediate goalpoint(s) reached before…	**Score level 1**	**Score level 2**	**Score level 3**
…half of trial time	200	350 per goalpoint	500 per goalpoint
…¾ of trial time	100	250 per goalpoint	400 per goalpoint
…end of trial time	50	150 per goalpoint	300 per goalpoint

Mission completion before…	**Score level 1**	**Score level 2**	**Score level 3**
…half of trial time	500	1000	1500
…¾ of trial time	375	750	1250
…end of trial time	250	500	1000