Eurathlon 2013
Scenario Application Paper (SAP) – Review Sheet

Team/Robot  Allen Vanguard/Armadillo
Scenario  Reconnaissance and surveillance in urban structures

For each of the following aspects, especially concerning the team’s approach to scenario-specific challenges, please give a short comment whether they are covered adequately in the SAP.

*Keep in mind that this evaluation, albeit anonymized, will be published online; private comments to the organizers should be sent separately.*

Robot Hardware
The Armadillo is a commercial robot designed for USAR. The vehicle is able to climb stairs and drive on very rugged terrain thanks to its 6 wheels but requires a special kit fitted for stair climbing and rough terrain.

Processing
As far as I can see, processing on-board is very limited as the vehicle is purely teleoperated. The architecture is not described but a distributed architecture is mentioned.

Communication
Based on wireless lan at 2400Mhz. Claims ranges of up to 300m in direct line of sight and 150m otherwise. Again, the system is completely teleoperated and if communications are lost, repositioning of antennas is the only option.

Localization
Based on GPS. No other sensor used apart from visual odometry from cameras by pilot.

Sensing
4 low light cameras. Processing is done by operator.

Vehicle Control
Teleoperated with need for an expert pilot to control multiple parameters that can be adjusted (not a lot of details given).

System Readiness
In operation since 2010 and claims TRL9 but that must be only for simple scenarios.

Overall Adequacy to Scenario-Specific Challenges
Very proficient for application but lack autonomy. This in itself is not a problem for successfully completing the task. This vehicle would give us a good benchmark on where the commercial state of the art is for teleoperated systems.
Common Scenario Problems and Considerations
ARMADILLO V4.0

Vehicle

The Armadillo V4.0 is a commercially available platform which has been available in various guises since 2010; the system has been sold to various police or military units across the globe and continues to be used domestically and in the fight against global terrorism. The Armadillo is a lightweight throwable UGV which utilises COFDM wireless technology. As standard its drive is transmitted via four conformal wheels which can be replaced with a track or stair climbing system. When used without accessories, the system can flip upside down and the cameras automatically self-right. The Armadillo’s controller can accommodate up to eight UGVs pre-loaded allowing the operator to switch from one to the other as the mission requires.

The Armadillos key capabilities are it is a robust; strong and effective UGV and has been in service for almost four years. In various tests for different customers we have demonstrated in excess of three hours constant usage over a typical mission. The distances operated on vary due to topography, interference and permissible transmitted power – generally speaking we demonstrate greater than 300m line of sight operations and greater than 200m non-line of sight.

The system is rugged and can be used extensively in an outdoor environment and can be used on a mixture of off-road/rough terrain subject to ground clearance. The track kit improves traction and its off-road capability and when combined with its manipulator arm it is possible to pass over numerous obstacles.

The design and construction of the Armadillo has considered rain and humidity throughout and has attained an IP rating of IP65 providing an effective seal against the environment and subsequent decontamination.

The system can climb over obstacles in general terms the same height as its inflated tyre, as with all systems it requires traction and will basically push and pull itself over the obstacle – the push and pull will depend on the centre of the mass. The Manipulator Arm can be adjusted to shift the centre of mass to advantage.

Where soft ground is encountered and the standard wheel configuration is deemed inappropriate the conformable wheels can be replaced with a track kit which offers even higher degrees of traction and thereby providing exception cross country capability.

When fitted with a Manipulator Arm and the stair climbing kit the Armadillo can ascend and descend 40° stairs with little or no preparation, it is possible to ascend steeper inclines but traction becomes very important.

Communication

The Armadillo system uses commercial off the shelf (COTS) COFDM Video and FHSS telemetry for data. The system can use internal antennas mounted in the lid of the Control Display System (CDS for short), alternatively to obtain greater range a highly mobile Integrated Situational
Awareness Network (iSAN) Bridge can be used connected direct to the Controller or remoted forward to further enhance operational performance.

As mentioned previously we expect the system to achieve wireless operational distances ≥300m line of sight operations and greater than 200m non-line of sight but this is wholly dependent on the area of operations.

Weather can obviously influence the effective performance of any wireless system, however certain climatic conditions affect wireless transmissions more significantly, and these may include rain and humidity. Our experience in deploying remotely operated systems in multiple environments allows us to provide our End Users with practical guidance to mitigate some of the reduction in performance.

When there are temporary communication failures or interruptions, this tele-operated system will pause and hold its position until it receives the correct data packet for it to continue.

The use of a hard-wired cable ensures robustness of communications but can place limitations in the manner in which the UGV is driven. Communications can be enhanced by the use of a iSAN Bridge which could be used to increase overall range alternatively it could be used to transmit a short distance to the UGV in an adverse wireless environment, the station placed <50m from the area of operations.

**Localization**

The Armadillo V4.0 is fitted with a GPS and sonar range finder system. The GPS is used for outdoor localisation which is not viable in an indoor environment. The sonar is used to measure the distance of objects immediately in front of the UGV, the distance displayed on the CDS display.

As we all know GPS suffers from numerous problems including difficulty in finding satellites, interference or temporary blockings whether buildings or tree foliage, unfortunately we do not have any technology to counter this.

**Sensing**

The Armadillo V4.0 is fitted with four cameras as standard, GPS localisation and Sonar range finder. The standard cameras are mounted in the body of the chassis: front drive which also incorporates a 180° tilt mechanism; rear drive; LHS camera and RHS camera affording 360° lateral Field of View (FOV). The GPS is mounted internally and the sonar is mounted on the same tilt module for the front drive camera. Additional cameras can be mounted on the upper surface of the UGV offering enhanced capability.

The cameras provide the operator with good situational awareness, all cameras are fitted with infra-red and white LEDs IR illumination. All cameras are a low Lux and are therefore useful in low-light conditions. Currently the camera system is used exclusively by the operator.

The sensors have been chosen for their environmental and vibration suitability. As with the remainder of the UGV they are protected against the environment with an IP rating of IP65.
Vehicle Control

The Armadillo V4.0 UGV has a standard safety protocol, when power is removed from the drive, such as returning the drive joystick to a neutral position, the ROV motor drive holds it in position.

When training new operators we teach them progressive and regressive application of power when driving, it is smoother and better in the long term for the system, however, many new operators or those not routinely driving the system will release the drive joystick to stop the system, when this occurs abrupt braking happens, the ROV stops immediately!

Providing there is traction the Armadillo UGV can start on a steep hill and subject to angle continue making the ascent.

Currently the Armadillo UGV is purely tele-operated and all complex operations are managed by the operator whether path finding or obstacle avoidance/negotiation. There is no semi-autonomous or assistance functions with the current version of this UGV.

While not always possible due to the operational situation, the wireless connection is managed by the operator who is trained to avoid total loss of communications. While there is no autonomous recovery there a number of things the operator can attempt to recover communications such as reposition the antenna, move the control station to a new control point, change radio channel, remove/eliminate competing communications.

System Readiness

The system is fully functional and with the exception of product development has been in this condition since 2010 and should be considered TRL-9. Much of the product development is to address obsolescence issues, improvement in performance and non-standard requests from valued customers.

As the team are actively involved in generating sales and competing in equipment trials, the team maintain a high level of competency with the Defender ROV, that being said we have yet to conduct any field tests specifically for euRathlon. It is our intention to address this shortfall in the months immediately prior to the trials.
Reconnaissance and surveillance in urban structures (USAR)  
ARMADILLO V4.0

The Armadillo UGV has to be prepared specifically to be able to ascend stairs, this is achieved by the fitment of a Stair Climbing Kit and a Manipulator Arm. This obviously has the impact of changing the overall weight and centre of gravity but provides the User with the ability to ascend 45° stairs with ease. If the UGV has been initially deployed on an upper floor, the descent can be as the standard configuration (i.e. without Stair Climbing Kit and Manipulator Arm), the descent would appear a little more chaotic but the rugged Armadillo would tolerate this abuse and be able to be driven away on the level below.

Currently the only way the Armadillo UGV can navigate in collapsed structures is by the skill of the operator, initially assessing whether the Armadillo can pass and manually mapping the route taken, this is obviously a laborious task and where working individually manual mapping takes the operators hands of the controls, the tele-operated ROV therefore stationary.

The Armadillo UGV can be driven at maximum speed for the majority of tasks thereby minimising the time on task, as the UGV draws close to an obstacle, the proportional joystick can the eased off thereby reducing the speed ensuring the obstacle is negotiated with care. The UGV operator is taught to drive the system to its advantage some obstacles can be taken without adjustment; others as mentioned above may require greater consideration.

In buildings, there is unlikely to be any GPS reception and this sensor information is lost to the operator, currently there are no other means of localisation other than manual mapping with dead-reckoning.

Video telemetry can be relayed to the operator and recorded on a plug in device.

The Armadillo can easily pass through typical European doors but requires the door to be fully open or ajar. As the Armadillo is a tele-operated machine, when it encounters changing dead-ends or other non-static obstacles it is up to the operator to determine whether he can progress based on his knowledge of the UGVs capabilities and limitations.
Ensuring that the Armadillo has completely searched the place is a difficult task with a tele-operated UGV and is wholly dependent on the operator and his support team. Through study it has been determined when employing a UGV in a USAR situation it is preferable to use a two-man team, the second person can focus on search and localisation where the operator may focus more heavily on obstacle avoidance, negotiation and general health of the UGV.

At the end of the scenario time the UGV is recovered to the control station either wirelessly or manually, the Armadillo currently has no technology to recover itself to the start point.

The cameras selected for use on the Armadillo UGV were chosen for their optical performance which includes their automatic or switched adjustment depending on the lighting conditions. Each of the cameras benefit by having IR and white LEDs mounted alongside the camera units, the lights controlled via the control station. The sensors fitted on the Armadillo are able to adequately cope with smoke, dust and mud, as with the remainder of the UGV they are rated IP65.

While not always possible due to the operational situation, the wireless connection is managed by the operator who is trained to avoid total loss of communications. While there is no autonomous recovery there a number of things the operator can attempt to recover communications such as reposition the antenna, move the control station to a new control point, change radio channel, remove/eliminate competing communications.
Common Scenario Problems and Considerations
ARMADILLO V4.0

Vehicle

The Armadillo V4.0 is a commercially available platform which has been available in various guises since 2010; the system has been sold to various police or military units across the globe and continues to be used domestically and in the fight against global terrorism. The Armadillo is a lightweight throwable UGV which utilises COFDM wireless technology. As standard its drive is transmitted via four conformal wheels which can be replaced with a track or stair climbing system. When used without accessories, the system can flip upside down and the cameras automatically self-right. The Armadillo’s controller can accommodate up to eight UGVs pre-loaded allowing the operator to switch from one to the other as the mission requires.

The Armadillos key capabilities are it is a robust; strong and effective UGV and has been in service for almost four years. In various tests for different customers we have demonstrated in excess of three hours constant usage over a typical mission. The distances operated on vary due to topography, interference and permissible transmitted power – generally speaking we demonstrate greater than 300m line of sight operations and greater than 200m non-line of sight.

The system is rugged and can be used extensively in an outdoor environment and can be used on a mixture of off-road/rough terrain subject to ground clearance. The track kit improves traction and its off-road capability and when combined with its manipulator arm it is possible to pass over numerous obstacles.

The design and construction of the Armadillo has considered rain and humidity throughout and has attained an IP rating of IP65 providing an effective seal against the environment and subsequent decontamination.

The system can climb over obstacles in general terms the same height as its inflated tyre, as with all systems it requires traction and will basically push and pull itself over the obstacle – the push and pull will depend on the centre of the mass. The Manipulator Arm can be adjusted to shift the centre of mass to advantage.

Where soft ground is encountered and the standard wheel configuration is deemed inappropriate the conformable wheels can be replaced with a track kit which offers even higher degrees of traction and thereby providing exception cross country capability.

When fitted with a Manipulator Arm and the stair climbing kit the Armadillo can ascend and descend 40° stairs with little or no preparation, it is possible to ascend steeper inclines but traction becomes very important.

Communication

The Armadillo system uses commercial off the shelf (COTS) COFDM Video and FHSS telemetry for data. The system can use internal antennas mounted in the lid of the Control Display System (CDS for short), alternatively to obtain greater range a highly mobile Integrated Situational
Awareness Network (iSAN) Bridge can be used connected direct to the Controller or remoted forward to further enhance operational performance.

As mentioned previously we expect the system to achieve wireless operational distances $\geq 300$ m line of sight operations and greater than $200$ m non-line of sight but this is wholly dependent on the area of operations.

Weather can obviously influence the effective performance of any wireless system, however certain climatic conditions affect wireless transmissions more significantly, and these may include rain and humidity. Our experience in deploying remotely operated systems in multiple environments allows us to provide our End Users with practical guidance to mitigate some of the reduction in performance.

When there are temporary communication failures or interruptions, this tele-operated system will pause and hold its position until it receives the correct data packet for it to continue.

The use of a hard-wired cable ensures robustness of communications but can place limitations in the manner in which the UGV is driven. Communications can be enhanced by the use of a iSAN Bridge which could be used to increase overall range alternatively it could be used to transmit a short distance to the UGV in an adverse wireless environment, the station placed $<50$ m from the area of operations.

**Localization**

The Armadillo V4.0 is fitted with a GPS and sonar range finder system. The GPS is used for outdoor localisation which is not viable in an indoor environment. The sonar is used to measure the distance of objects immediately in front of the UGV, the distance displayed on the CDS display.

As we all know GPS suffers from numerous problems including difficulty in finding satellites, interference or temporary blockings whether buildings or tree foliage, unfortunately we do not have any technology to counter this.

**Sensing**

The Armadillo V4.0 is fitted with four cameras as standard, GPS localisation and Sonar range finder. The standard cameras are mounted in the body of the chassis: front drive which also incorporates a $180^\circ$ tilt mechanism; rear drive; LHS camera and RHS camera affording 360$^\circ$ lateral Field of View (FOV). The GPS is mounted internally and the sonar is mounted on the same tilt module for the front drive camera. Additional cameras can be mounted on the upper surface of the UGV offering enhanced capability.

The cameras provide the operator with good situational awareness, all cameras are fitted with infra-red and white LEDs IR illumination. All cameras are a low Lux and are therefore useful in low-light conditions. Currently the camera system is used exclusively by the operator.

The sensors have been chosen for their environmental and vibration suitability. As with the remainder of the UGV they are protected against the environment with an IP rating of IP65.
Vehicle Control

The Armadillo V4.0 UGV has a standard safety protocol, when power is removed from the drive, such as returning the drive joystick to a neutral position, the ROV motor drive holds it in position.

When training new operators we teach them progressive and regressive application of power when driving, it is smoother and better in the long term for the system, however, many new operators or those not routinely driving the system will release the drive joystick to stop the system, when this occurs abrupt braking happens, the ROV stops immediately!

Providing there is traction the Armadillo UGV can start on a steep hill and subject to angle continue making the ascent.

Currently the Armadillo UGV is purely tele-operated and all complex operations are managed by the operator whether path finding or obstacle avoidance/negotiation. There is no semi-autonomous or assistance functions with the current version of this UGV.

While not always possible due to the operational situation, the wireless connection is managed by the operator who is trained to avoid total loss of communications. While there is no autonomous recovery there a number of things the operator can attempt to recover communications such as reposition the antenna, move the control station to a new control point, change radio channel, remove/eliminate competing communications.

System Readiness

The system is fully functional and with the exception of product development has been in this condition since 2010 and should be considered TRL-9. Much of the product development is to address obsolescence issues, improvement in performance and non-standard requests from valued customers.

As the team are actively involved in generating sales and competing in equipment trials, the team maintain a high level of competency with the Defender ROV, that being said we have yet to conduct any field tests specifically for euRathlon. It is our intention to address this shortfall in the months immediately prior to the trials.
Reconnaissance and surveillance in urban structures (USAR)
ARMADILLO V4.0

The Armadillo UGV has to be prepared specifically to be able to ascend stairs, this is achieved by the fitment of a Stair Climbing Kit and a Manipulator Arm. This obviously has the impact of changing the overall weight and centre of gravity but provides the User with the ability to ascend 45° stairs with ease. If the UGV has been initially deployed on an upper floor, the descent can be as the standard configuration (i.e. without Stair Climbing Kit and Manipulator Arm), the descent would appear a little more chaotic but the rugged Armadillo would tolerate this abuse and be able to be driven away on the level below.

Currently the only way the Armadillo UGV can navigate in collapsed structures is by the skill of the operator, initially assessing whether the Armadillo can pass and manually mapping the route taken, this is obviously a laborious task and where working individually manual mapping takes the operators hands of the controls, the tele-operated ROV therefore stationary.

The Armadillo UGV can be driven at maximum speed for the majority of tasks thereby minimising the time on task, as the UGV draws close to an obstacle, the proportional joystick can the eased off thereby reducing the speed ensuring the obstacle is negotiated with care. The UGV operator is taught to drive the system to its advantage some obstacles can be taken without adjustment; others as mentioned above may require greater consideration.

In buildings, there is unlikely to be any GPS reception and this sensor information is lost to the operator, currently there are no other means of localisation other than manual mapping with dead-reckoning.

Video telemetry can be relayed to the operator and recorded on a plug in device.

The Armadillo can easily pass through typical European doors but requires the door to be fully open or ajar. As the Armadillo is a tele-operated machine, when it encounters changing dead-ends or other non-static obstacles it is up to the operator to determine whether he can progress based on his knowledge of the UGVs capabilities and limitations.
Ensuring that the Armadillo has completely searched the place is a difficult task with a tele-operated UGV and is wholly dependent on the operator and his support team. Through study it has been determined when employing a UGV in a USAR situation it is preferable to use a two-man team, the second person can focus on search and localisation where the operator may focus more heavily on obstacle avoidance, negotiation and general health of the UGV.

At the end of the scenario time the UGV is recovered to the control station either wirelessly or manually, the Armadillo currently has no technology to recover itself to the start point.

The cameras selected for use on the Armadillo UGV were chosen for their optical performance which includes their automatic or switched adjustment depending on the lighting conditions. Each of the cameras benefit by having IR and white LEDs mounted alongside the camera units, the lights controlled via the control station. The sensors fitted on the Armadillo are able to adequately cope with smoke, dust and mud, as with the remainder of the UGV they are rated IP65.

While not always possible due to the operational situation, the wireless connection is managed by the operator who is trained to avoid total loss of communications. While there is no autonomous recovery there a number of things the operator can attempt to recover communications such as reposition the antenna, move the control station to a new control point, change radio channel, remove/eliminate competing communications.
Eurathlon 2013
Scenario Application Paper (SAP) – Review Sheet

Team/Robot       Allen Vanguard / Defender D2.1
Scenario         Reconnaissance and Surveillance in Urban Structures (USAR)

For each of the following aspects, especially concerning the team’s approach to scenario-specific challenges, please give a short comment whether they are covered adequately in the SAP.

* Keep in mind that this evaluation, albeit anonymized, will be published online; private comments to the organizers should be sent separately. *

Robot Hardware
The robot hardware adequately covers the scenario, providing the stairs are no more than 40 degrees incline. The robot design has an IP55. The SAP doesn’t give information about the robot dimensions, however it says the robot can pass through typical European doors.

Processing
The SAP does not detail the robot’s processing, but since the team is going to tele-operate the vehicle this is not so critical.

Communication
The robot communication adequately covers the scenario requirements, using a commercial off the shelf (COTS) 2.4GHz WLAN transceiver system that transmits bi-directional data/audio and one dual video stream. The system is expected to achieve wireless operational distances ≥ 1000m line of sight operations and greater than 300m non-line of sight. The wireless connection is managed by the operator who is trained to avoid a total loss of communication by repositioning the antenna, moving the control station to a new control point, changing radio channel, etc.

Localization
The robot is tele-operated by the team thus localisation will be the task of the robot’s operator.

Sensing
The robot is adequately equipped with sensors: 6 cameras (three fitted with LEDs and one with IR illumination), a GPS localisation and an attitude indicator. All sensors are IP55.

Vehicle Control
The vehicle is purely tele-operated by two operators via wireless communication.

System Readiness
Technology Readiness is considered to be high at a TRL 9.
Eurathlon 2013

Overall Adequacy to Scenario-Specific Challenges

The SAP section about how to cover scenario-specific challenges is very good. The overall adequacy of the robot to the scenario-specific challenges appears to be high. Information about the robot dimensions would be helpful. If possible, a more autonomous performance would be desirable.
Common Scenario Problems and Considerations
DEFENDER D2.1

Vehicle

The Defender D2.1 is a commercially available platform which has been available in various guises since 2003; the system has been sold to various police or military units across the globe and continues to be used in the fight against global terrorism. The Defenders major characteristics include: six wheel drive, each independently driven; the ROV is constructed mostly using titanium which gives a great weight to strength capability (the system weighs 275kg\(^1\)); it utilises distributed computer architecture and is modular in construction.

The Defenders key capabilities are it is a robust; reliable; strong and effective ROV and has been in service for more than a decade. In various tests for different customers we have demonstrated in excess of four hours constant usage over a typical mission. The distances operated on vary due to topography, interference and permissible transmitted power – generally speaking we demonstrate >1000m line of sight operations and greater than 300m non-line of sight.

The system has exceptional outdoor/off-road/rough terrain capability derived from its six wheel drive, independently driven chassis which also incorporates articulating front and rear axles.

The design and construction of the Defender has considered rain and humidity throughout and has attained an IP rating of IP55 providing an effective seal against the environment and subsequent decontamination.

The system can climb over obstacles in general terms the same height as its inflated tyre, as with all systems it requires traction and will basically push and pull itself over the obstacle – the push and pull will depend on the centre of the mass. The Arm Assembly can be adjusted to shift the centre of mass to advantage. Where traction may be an issue the tyres can be manually deflated providing a wider profile attaining higher levels of grip.

Where soft ground is encountered the standard profile of the inflated tyre is normally wider than tracks used by many of the Defenders contemporaries and with each being driven it provides exception cross country capability, as mentioned above the tyres can be manually deflated to further enhance this capability.

The Defender can open and pass through typical European doors. The opening part takes a small amount of learning especially where the door is opening towards the robot and is on a spring return but once mastered the room/building is easily accessed. Where doors are locked other means are required including the Defender’s brute strength.

The Defender can ascend and descend 40° stairs with little or no preparation, it is possible to ascend steeper inclines but traction becomes very important.

\(^1\) When fitted with cameras but without accessories.
Communication

The Defender system uses commercial off the shelf (COTS) 2.4GHz WLAN transceiver system, transmitting bi-directional data/audio and one direction dual video stream. The system can use antennas internal to the Command Console, alternatively to obtain greater range a higher db external antenna. Alternatively a relay station can be forward located up to 150m from the Console to further enhance operational performance.

As mentioned previously we expect the system to achieve wireless operational distances ≥1000m line of sight operations and greater than 300m non-line of sight but this is wholly dependent on the area of operations.

Weather can obviously influence the effective performance of any wireless system, however certain climatic conditions affect WLAN more significantly, and these may include rain and humidity. Our experience in deploying remotely operated systems in multiple environments allows us to provide our End Users with practical guidance to mitigate the reduction in performance.

As our primary application is the use of this system in an EOD/IEDD situation it utilises a robust and detailed safety protocol system which checks and checks again the command, mobility and firing circuits. If there is any deviation from the correct command sequence such as a temporary communication failure, the system halts all movement or in the case of firing sequences, it stops. This sequence whether mobility or firing circuit fails safe! It will remain in this condition until it receives the correct command sequence which has then been verified with.

The use of a hard-wired cable ensures robustness of communications but can place limitations in the manner in which the ROV is driven. Communications can be enhanced by the use of a Relay Station which could be used to increase overall range alternatively it could be used to transmit a short distance to the ROV in an adverse wireless environment, the station placed <50m from the area of operations.

Localization

The Defender ROV is fitted with a GPS system for localisation which is used in one of two modes: basic or advanced, however neither of these are applicable in an indoor environment.

Basic. The Basic system provides a feed on the Graphical User Interface (the console) and provides basic information such as latitude & longitude readings; elevation above sea level; speed; vector distance travelled and path distance travelled.

Advanced. The Advanced system builds on from the basic and is primarily used in CBRN applications. It is used in conjunction with CBR and meteorological sensors and pre-loaded mapping (offline). The CBR sensors held on the ROV utilise its telemetry to convey status and alarm information back to the Command Console. When an alarm is raised an Application takes a GPS reading, wind direction and speed, ambient temperature and when manually input information is added provides a downwind hazard template.

As we all know GPS suffers from numerous problems including difficulty in finding satellites, interference or temporary blockings whether buildings or tree foliage, unfortunately we do not have any technology to counter this.
Sensing

The Defender ROV is fitted with six cameras, GPS localisation and an attitude indicator. The cameras are mounted as follows: front drive; rear drive; turret camera; upper arm; wrist; claw. The GPS is mounted on the rear of the upper arm and the attitude indicator inside the vehicle control unit.

The cameras provide the operator with good situational awareness, three are fitted with LEDs, and a fourth has IR illumination. All cameras are a low Lux and are therefore useful in low-light conditions. Currently the camera system is used exclusively by the operator.

The choice of the above sensors and their position have derived out of many years of design and operational application. They have repeated demonstrated their suitability whether vibration through driving, weapons firing or in close proximity to a functioning explosive device. As with the remainder of the ROV they are protected against the environment with an IP rating of IP55.

Vehicle Control

As mentioned above the Defender ROV has a robust safety protocol, in addition when power is removed from the drive, such as returning the drive joystick to a neutral position, the ROV brakes are applied. Providing the brakes have traction they will hold the Defender in position.

When training new operators we teach them progressive and regressive application of power when driving, it is smoother and better in the long term for the system, however, many new operators or those not routinely driving the system will release the drive joystick to stop the system, when this occurs abrupt braking happens, the ROV stops immediately!

Providing there is traction the Defender ROV can start on a steep hill and subject to angle continue making the ascent.

As with increasing or decreasing drive power, the best method of turning is a gradual or incremental turn, skid steer if you will. However in some situations a sharp turn is necessary, the Defender ROV can turn on the spot (and thereby turn in a small space relative to its size), with one side of the drive train working in an opposite direction to the other.

Currently the Defender ROV is purely tele-operated and all complex operations are managed by the operator whether path finding or obstacle avoidance/negotiation. There is no semi-autonomous or assistance functions with the current version of Defender ROV.

While not always possible due to the operational situation, the wireless connection is managed by the operator who is trained to avoid total loss of communications. While there is no autonomous recovery there a number of things the operator can attempt to recover communications such as reposition the antenna, move the control station to a new control point, change radio channel, remove/eliminate competing communications.

System Readiness

The system is fully functional and with the exception of product development has been in this condition since 2003 and should be considered TRL-9. Much of the product development is to
address obsolescence issues, improvement in performance and non-standard requests from valued customers.

As the team are actively involved in generating sales and competing in equipment trials, the team maintain a high level of competency with the Defender ROV, that being said we have yet to conduct any field tests specifically for euRathlon. It is our intention to address this shortfall in the months immediately prior to the trials.
Reconnaissance and surveillance in urban structures (USAR) DEFENDER D2.1

Traction is another crucial factor when ascending/descending obstacles in urban structures particularly stairs. The Defender can ascend and descend 40° stairs with little or no preparation, it is possible to ascend steeper inclines but traction becomes very important and it is essential to consider the configuration of the ROV and maybe remove the air from all the tyres.

Currently the only way the Defender ROV can navigate in collapsed structures is by the skill of the operator, initially assessing whether the Defender can pass and manually mapping the route taken, this is obviously a laborious task and where working individually manual mapping takes the operators hands of the controls, the tele-operated ROV therefore stationary.

The Defender ROV can be driven at maximum speed for the majority of tasks thereby minimising the time on task, as the ROV draws close to an obstacle, the proportional joystick can the eased off thereby reducing the speed ensuring the obstacle is negotiated with care. The ROV operator is taught to drive the system to its advantage some obstacles can be taken without adjustment; others as mentioned above may require greater consideration.

In buildings, there is unlikely to be any GPS reception and this sensor information is lost to the operator, currently there are no other means of localisation other than manual mapping with dead-reckoning.

Video telemetry and the ability to take a snapshot can be relayed to the operator.

The Defender can open and pass through typical European doors. The opening part takes a small amount of learning especially where the door is opening towards the robot and is on a spring return but once mastered the room/building is easily accessed. Where doors are locked or jammed other means are required including the Defender’s brute strength.

As the Defender is a tele-operated machine, when it encounters changing dead-ends or other non-static obstacles it is up to the operator to determine whether he can progress based on his knowledge of the ROVs capabilities and limitations.

Ensuring that the Defender has completely searched the place is a difficult task with a tele-operated ROV and is wholly dependent on the operator and his support team. Through study it has been determined when employing a ROV in a USAR situation it is preferable to use a two-man team, the second person can focus on search and localisation where the operator may focus more heavily on obstacle avoidance, negotiation and general health of the ROV.
At the end of the scenario time the ROV is recovered to the control station either wirelessly or manually, the Defender currently has no technology to recover itself to the start point.

The cameras selected for use on the Defender ROV where chosen for their optical performance which includes their automatic or switched adjustment depending on the lighting conditions. Three of the cameras also benefit by having LEDs mounted on the camera unit, the lights controlled via the control station. The sensors fitted on the Defender are able to adequately cope with smoke, dust and mud, as with the remainder of the ROV they are rated IP55.

While not always possible due to the operational situation, the wireless connection is managed by the operator who is trained to avoid total loss of communications. While there is no autonomous recovery there a number of things the operator can attempt to recover communications such as reposition the antenna, move the control station to a new control point, change radio channel, remove/eliminate competing communications.
Eurathlon 2013
Scenario Application Paper (SAP) – Review Sheet

Team/Robot  Allen Vanguard/Digital Vanguard
Scenario       Reconnaissance and surveillance in urban structures (USAR)

For each of the following aspects, especially concerning the team’s approach to scenario-specific challenges, please give a short comment whether they are covered adequately in the SAP.

Keep in mind that this evaluation, albeit anonymized, will be published online; private comments to the organizers should be sent separately.

Robot Hardware
The used robot is the Digital Vanguard, a commercially available platform which has been available in various guises since 2003. Features:
- Track driven;
- Low centre of gravity each independently driven;
- Uses distributed computer architecture allowing integration of sensors;
- Arm Assembly with 6DOF.

Processing
No detailed information from the paper.

Communication
The Digital Vanguard system uses commercial off the shelf (COTS) 2.4GHz WLAN transceiver system, transmitting bi-directional data/audio and one direction dual video stream. Possibly, a cable can be used for communications.

Localization
The Digital Vanguard ROV is not currently fitted with a GPS system. No localization sensors appear to be present.

Sensing
The Digital Vanguard ROV is fitted as standard with three cameras; a fourth can be added as required by the mission

Vehicle Control
The vehicle has a robust safety protocol. When power is removed from the drive, such as returning the drive joystick to a neutral position, the ROV brakes are applied. Providing the brakes have traction they will hold the Defender in position.
The system is tele-operated and there does not seem from the paper there is some automatic support to the operator.
Eurathlon 2013

System Readiness
The system is fully functional and with the exception of product development has been in this condition since 2003 and should be considered TRL-9.

Overall Adequacy to Scenario-Specific Challenges
The vehicle is robust. However, no automatic assistance tools are given to the operator. This may be an issue in the addressed scenario. From 0-5 I would say 3.5.
Common Scenario Problems and Considerations
DIGITAL VANGUARD

Vehicle

The Digital Vanguard is a commercially available platform which has been available in various guises since 2003; the system has been sold to various police or military units across the globe and continues to be used in the fight against global terrorism.

The Digital Vanguards major characteristics include:
- Track driven,
- Low centre of gravity each independently driven;
- Uses distributed computer architecture allowing integration of sensors
- Arm Assembly with 6DOF

The Digital Vanguards key capabilities are it is a robust; reliable; strong and effective ROV and has been in service for more than a decade. In various tests for different customers we have demonstrated up to four hours constant usage over a typical mission. The distances operated on vary due to topography, interference and permissible transmitted power – generally speaking we demonstrate >1000m line of sight operations and greater than 300m non-line of sight.

The system has exceptional outdoor/off-road/rough terrain capability derived from high torque motors and its centre of gravity riding low between its drive system. The drive assembly has been optimised to assist climbing whether obstacles or stairs, in addition a lift kit can be fitted to enhance the ride height and improve obstacle clearance.

The design and construction of the Digital Vanguard has considered rain and humidity throughout and has attained an IP rating of IP65 providing an effective seal against the environment and subsequent decontamination.

The system can climb over obstacles >50cm due to its high torque drive and low centre of gravity as with all systems it requires traction and will basically push and pull itself over the obstacle – the push and pull will depend on the centre of the mass. The Arm Assembly can be adjusted to shift the centre of mass to advantage.

Where soft ground is encountered the Digital Vanguard can be fitted with a lift kit while widening the width of the ROV it increases the ground clearance assisting crossing mixed terrain.

The Digital Vanguard can ascend and descend 45° stairs without any specific preparation; it is possible to ascend steeper inclines remembering that traction is very important.
Communication

The Digital Vanguard system uses commercial off the shelf (COTS) 2.4GHz WLAN transceiver system, transmitting bi-directional data/audio and one direction dual video stream. The system can use antennas internal to the Command Console, alternatively to obtain greater range a higher db external antenna. Alternatively a relay station can be forward located up to 150m from the Console to further enhance operational performance.

As mentioned previously we expect the system to achieve wireless operational distances ≥1000m line of sight operations and greater than 300m non-line of sight but this is wholly dependent on the area of operations.

Weather can obviously influence the effective performance of any wireless system, however certain climatic conditions affect WLAN more significantly, and these may include rain and humidity. Our experience in deploying remotely operated systems in multiple environments allows us to provide our End Users with practical guidance to mitigate the reduction in performance.

As our primary application is the use of this system in an EOD/IEDD situation it utilises a robust and detailed safety protocol system which checks and checks again the command, mobility and firing circuits. If there is any deviation from the correct command sequence such as a temporary communication failure, the system halts all movement or in the case of firing sequences, it stops. This sequence whether mobility or firing circuit fails safe! It will remain in this condition until it receives the correct command sequence which has then been verified with.

The use of a hard-wired cable ensures robustness of communications but can place limitations in the manner in which the ROV is driven. Communications can be enhanced by the use of a Relay Station which could be used to increase overall range alternatively it could be used to transmit a short distance to the ROV in an adverse wireless environment, the station placed <50m from the area of operations.

Localization

The Digital Vanguard ROV is not currently fitted with a GPS system.

Sensing

The Digital Vanguard ROV is fitted as standard with three cameras; a fourth can be added as required by the mission. The cameras are mounted as follows: front drive; claw and Pan, Tilt & Zoom. The fourth camera plugs into the upper arm and used as a disruptor camera, IR camera, or flexible camera for use with deployment tools.

The cameras provide the operator with good situational awareness, three are fitted with LEDs, and a fourth additional has IR illumination. All cameras are a low Lux and are therefore useful in low-light conditions. Currently the camera system is used exclusively by the operator.

The choice of the above sensors and their position have derived out of many years of design and operational application. They have repeated demonstrated their suitability whether vibration through driving, weapons firing or in close proximity to a functioning explosive device. As with the remainder of the ROV they are protected against the environment with an IP rating of IP65.
Vehicle Control

As mentioned the Digital Vanguard ROV has a robust safety protocol, in addition when power is removed from the drive, such as returning the drive joystick to a neutral position, the drive mechanism is locked in position. Providing the ROV/tracks have traction they will hold the Digital Vanguard in position.

When training new operators we teach them progressive and regressive application of power when driving, it is smoother and better in the long term for the system, however, many new operators or those not routinely driving the system will release the drive joystick to stop the system, when this occurs abrupt braking happens, the ROV stops immediately!

Providing there is traction the Digital Vanguard ROV can start on a steep hill and subject to the incline, continue making the ascent.

As with increasing or decreasing drive power, the best method of turning is a gradual or incremental turn, skid steer if you will. However in some situations a sharp turn is necessary, the Digital Vanguard ROV can turn on the spot (and thereby turn in a small space relative to its size), with one side of the drive train working in an opposite direction to the other.

Currently the Digital Vanguard ROV is purely tele-operated and all complex operations are managed by the operator whether path finding or obstacle avoidance/negotiation. There is no semi-autonomous or assistance functions with the current version of Digital Vanguard ROV.

While not always possible due to the operational situation, the wireless connection is managed by the operator who is trained to avoid total loss of communications. While there is no autonomous recovery there a number of things the operator can attempt to recover communications such as reposition the antenna, move the control station to a new control point, change radio channel, remove/eliminate competing communications.

System Readiness

The system is fully functional and with the exception of product development has been in this condition since 2003 and should be considered TRL-9. Much of the product development is to address obsolescence issues, improvement in performance and non-standard requests from valued customers.

As the team are actively involved in generating sales and competing in equipment trials, the team maintain a high level of competency with the Digital Vanguard ROV, that being said we have yet to conduct any field tests specifically for euRathlon. It is our intention to address this shortfall in the months immediately prior to the trials.
Reconnaissance and surveillance in urban structures (USAR)
DIGITAL VANGUARD

Traction is another crucial factor when ascending/descending obstacles in urban structures particularly stairs. The Digital Vanguard can ascend and descend 45° stairs without any specific preparation, it is possible to ascend steeper inclines but traction becomes very important and it is essential to consider the configuration of the ROV before making an attempt.

Currently the only way the Digital Vanguard ROV can navigate in collapsed structures is by the skill of the operator, initially assessing whether the Digital Vanguard can pass and manually mapping the route taken, this is obviously a laborious task and where working individually manual mapping takes the operators hands of the controls, the tele-operated ROV therefore stationary.

The Digital Vanguard ROV can be driven at maximum speed for the majority of tasks thereby minimising the time on task, as the ROV draws close to an obstacle, the proportional joystick can be eased off thereby reducing the speed ensuring the obstacle is negotiated with care. The ROV operator is taught to drive the system to its advantage some obstacles can be taken without adjustment; others as mentioned above may require greater consideration.

In buildings, there is unlikely to be any GPS reception and this sensor information is lost to the operator, currently there are no other means of localisation other than manual mapping with dead-reckoning.

Video telemetry and the ability to take a snapshot can be relayed to the operator at any time there is communications with the system.

The Digital Vanguard can open and pass through typical European doors. The opening part takes a small amount of learning especially where the door is opening towards the robot and is on a spring return but once mastered the room/building is easily accessed. Where doors are locked or jammed other means are required including the Defender’s brute strength.

As the Digital Vanguard is a tele-operated machine, when it encounters changing dead-ends or other non-static obstacles it is up to the operator to determine whether he can progress based on his knowledge of the ROVs capabilities and limitations.
Ensuring that the Digital Vanguard has completely searched the place is a difficult task with a tele-operated ROV and is wholly dependent on the operator and his support team. Through study it has been determined when employing a ROV in a USAR situation it is preferable to use a two-man team, the second person can focus on search and localisation where the operator may focus more heavily on obstacle avoidance, negotiation and general health of the ROV.

At the end of the scenario time the ROV is recovered to the control station either wirelessly or manually, the Digital Vanguard currently has no technology to recover itself to the start point.

The cameras selected for use on the Digital Vanguard ROV where chosen for their optical performance which includes their automatic or switched adjustment depending on the lighting conditions. The three standard cameras benefit by having LEDs mounted on or near the camera unit, the lights controlled via the control station. The sensors fitted on the Digital Vanguard are able to adequately cope with smoke, dust and mud, as with the remainder of the ROV they are rated IP65.

While not always possible due to the operational situation, the wireless connection is managed by the operator who is trained to avoid total loss of communications. While there is no autonomous recovery there a number of things the operator can attempt to recover communications such as reposition the antenna, move the control station to a new control point, change radio channel, remove/eliminate competing communications.
Eurathlon 2013

Scenario Application Paper (SAP) – Review Sheet

Team/Robot  Allen Vanguard/Scorpion UGV
Scenario  Reconnaissance and surveillance in urban structures (USAR)

For each of the following aspects, especially concerning the team’s approach to scenario-specific challenges, please give a short comment whether they are covered adequately in the SAP.

*Keep in mind that this evaluation, albeit anonymized, will be published online; private comments to the organizers should be sent separately.*

Robot Hardware
The Scorpion UGV has the capability to ascend or descend sharp stairs as well as operate in hard environmental conditions (ready for extended temperature range, IP65 rating, etc.). Also, it has a proper size to pass through standard doors.

Processing
The robot does not perform much on-board processing since the system is purely tele-operated.

Communication
The robot uses COTS wireless systems using advanced technologies such as CODFM and FHSS. Maybe the only weak point about communications, it is the fact that they expect only 200m for non-line of sight operations. This fact along with a low autonomy level can reduce the applications where this system could be properly used.

Localization
The system counts with a GPS for outdoor localization and a sonar for obstacle detection. Both sensors are just used to help guiding the operator since no autonomy level makes use of these navigation sensors. Also, the robot does not count with any sensor that can be used to create a map of the inside of the structure to localize the OPIs, as requested in the USAR scenario description. Also, it is not mentioned if the system counts with a IMU sensor in order to help the operator to know the exact attitude of the robot. This could be of special interest when the robot is climbing stairs or it is not navigating on a flat terrain.

Sensing
The standard sensor suite of the Scorpion robot is formed by 4 cameras, GPS and a sonar sensor. The cameras count with LED illumination and are prepared for low illumination environments. However, as commented above, there is no sensor or system that could be used to create a map of the inside of the structure as commented in the USAR scenario description.

Vehicle Control
The robot is completely tele-operated and it does not implement any assistance mode.
Eurathlon 2013

System Readiness
The system has been used for real operation since the last three years. Then, the technology system readiness is high.

Overall Adequacy to Scenario-Specific Challenges
From the configuration point of view, the robot is prepared for the USAR scenario except for the fact that it does not count with any solution in order to create a map of the inside of the structure as required in the USAR scenario description. This requirement has not been addressed by the proposed solution. We think that the team should try to implement a solution, even with human-in-the-loop, in order to fulfill all the tasks of the scenario. Also, the level of autonomy is low and this could penalize the time or number of operators required to perform the whole mission.
Common Scenario Problems and Considerations
SCORPION UGV

Vehicle

The Scorpion is a commercially available platform which has been available in various guises since 2010; the system has been sold to various police or military units across the globe and continues to be used in the fight against global terrorism, it can be used for search and surveillance, reconnaissance and used for the inspection of buildings, caves tunnels and targets of interest. The Scorpion major characteristics include: four wheel track drive system, the UGV weighs 9kg\(^1\), and can be mounted with numerous accessories including sensors to assist in search and CBRN hazards.

The Scorpion key capabilities are it is a robust; strong and effective UGV and has been in service for more than three years. In various tests for different customers we have demonstrated in excess of three hours constant usage over a typical mission. The distances operated on vary due to topography, interference and permissible transmitted power – generally speaking we demonstrate 300m line of sight operations and greater than 300m non-line of sight.

The system has exceptional outdoor/off-road/rough terrain capability derived from its torque motors and track system.

The design and construction of the Scorpion has considered rain and humidity throughout and has attained an IP rating of IP65 and an operating temperature range of \(-20^\circ\text{C}\) to \(+60^\circ\text{C}\). The system is effectively sealed against the environment and subsequent decontamination.

The system can climb over obstacles in general terms the same height as its track system, as with all systems it requires traction and will basically push and pull itself over the obstacle – the push and pull will depend on the centre of the mass. When fitted with a manipulator arm the Scorpion can climb higher obstacles and the arm can be adjusted to shift the centre of mass to advantage.

Where soft ground is encountered the Scorpion has exceptional cross country capability, and can pass through ajar or open European doors. Where doors are closed and/or locked other means are required.

The Scorpion can ascend and descend 45° stairs when fitted with a manipulator arm. When deployed on upper levels of a structure and the only direction of travel is down the manipulator arm is not essential for descent, the robust construction of the Scorpion permits a rapid if chaotic descent.

Communication

The Scorpion system uses commercial off the shelf (COTS) COFDM Video and FHSS telemetry for data. The system can use internal antennas mounted in the lid of the Control Display System (CDS for short), alternatively to obtain greater range a highly mobile Integrated Situational

---

\(^1\) Without accessories
Awareness Network (iSAN) Bridge can be used connected direct to the Controller or remoted forward to further enhance operational performance.

As mentioned previously we expect the system to achieve wireless operational distances of approximately 300m line of sight operations and approximately 200m non-line of sight but this is wholly dependent on the area of operations.

Weather can obviously influence the effective performance of any wireless system, however certain climatic conditions affect wireless transmissions more significantly, and these may include rain and humidity. Our experience in deploying remotely operated systems in multiple environments allows us to provide our End Users with practical guidance to mitigate the reduction in performance.

When there are temporary communication failures or interruptions, this tele-operated system will pause and hold its position until it receives the correct data packet for it to continue.

The use of a hard-wired cable ensures robustness of communications but can place limitations in the manner in which the UGV is driven. Communications can be enhanced by the use of a iSAN Bridge which could be used to increase overall range alternatively it could be used to transmit a short distance to the UGV in an adverse wireless environment, the station placed <50m from the area of operations.

**Localization**

The Scorpion is fitted with a GPS and sonar range finder system. The GPS is used for outdoor localisation which is not viable in an indoor environment. The sonar is used to measure the distance of objects immediately in front of the UGV, the distance displayed on the CDS display.

As we all know GPS suffers from numerous problems including difficulty in finding satellites, interference or temporary blockings whether buildings or tree foliage, unfortunately we do not have any technology to counter this.

**Sensing**

The Armadillo V4.0 is fitted with four cameras as standard, GPS localisation and Sonar range finder. The standard cameras are mounted in the body of the chassis: front drive which also incorporates a 180° tilt mechanism; rear drive; LHS camera and RHS camera affording 360° lateral Field of View (FOV). The GPS is mounted internally and the sonar is mounted on the same tilt module for the front drive camera. Additional cameras can be mounted on the upper surface of the UGV offering enhanced capability.

The cameras provide the operator with good situational awareness, all cameras are fitted with infra-red and white LEDs providing effective all round illumination. All cameras are a low Lux and are therefore useful in low-light conditions. Currently the camera system is used exclusively by the operator.

The sensors have been chosen for their environmental and vibration suitability. As with the remainder of the UGV they are protected against the environment with an IP rating of IP65.
Vehicle Control

The Scorpion UGV has a standard safety protocol, when power is removed from the drive, such as returning the drive joystick to a neutral position, the ROV motor drive holds it in position.

When training new operators we teach them progressive and regressive application of power when driving, it is smoother and better in the long term for the system, however, many new operators or those not routinely driving the system will release the drive joystick to stop the system, when this occurs abrupt braking happens, the ROV stops immediately!

Providing there is traction the Scorpion UGV can start on a steep hill and subject to angle continue making the ascent.

Currently the Scorpion UGV is purely tele-operated and all complex operations are managed by the operator whether path finding or obstacle avoidance/negotiation. There is no semi-autonomous or assistance functions with the current version of this UGV.

While not always possible due to the operational situation, the wireless connection is managed by the operator who is trained to avoid total loss of communications. While there is no autonomous recovery there a number of things the operator can attempt to recover communications such as reposition the antenna, move the control station to a new control point, change radio channel, remove/eliminate competing communications.

System Readiness

The system is fully functional and with the exception of product development has been in this condition since 2010 and should be considered TRL-9. Much of the product development is to address obsolescence issues, improvement in performance and non-standard requests from valued customers.

As the team are actively involved in generating sales and competing in equipment trials, the team maintain a high level of competency with the Scorpion ROV, that being said we have yet to conduct any field tests specifically for euRathlon. It is our intention to address this shortfall in the months immediately prior to the trials.
Reconnaissance and surveillance in urban structures (USAR)

SCORPION UGV

The Scorpion UGV has to be prepared specifically to be able to ascend stairs, this is achieved by the rapid fitment of a Manipulator Arm. This obviously has the impact of changing the overall weight and centre of gravity but provides the User with the ability to ascend 45° stairs with ease. If the UGV has been initially deployed on an upper floor, the descent can be as the standard configuration (i.e. without Stair Climbing Kit and Manipulator Arm), the descent would appear a little more chaotic but the rugged Armadillo would tolerate this abuse and be able to be driven away on the level below.

Currently the only way the Scorpion UGV can navigate in collapsed structures is by the skill of the operator, initially assessing whether the Scorpion can pass and manually mapping the route taken, this is obviously a laborious task and where working individually manual mapping takes the operators hands of the controls, the tele-operated UGV therefore stationary.

The Scorpion UGV can be driven at maximum speed for the majority of tasks thereby minimising the time on task, as the UGV draws close to an obstacle, the proportional joystick can the eased off thereby reducing the speed ensuring the obstacle is negotiated with care. Alternatively the operator can select crawl mode which limits the amount of power delivered to the drive system and thereby exercising a higher level of precision. The UGV operator is taught to drive the system to its advantage some obstacles can be taken without adjustment; others as mentioned above may require greater consideration.

In buildings, there is unlikely to be any GPS reception and this sensor information is lost to the operator, currently there are no other means of localisation other than manual mapping with dead-reckoning.

Video telemetry can be relayed to the operator and recorded on a plug in device.

The Scorpion can easily pass through typical European doors but requires the door to be fully open or slightly ajar. As the Scorpion is a tele-operated machine, when it encounters changing dead-ends or other non-static obstacles it is up to the operator to determine whether he can progress based on his knowledge of the UGVs capabilities and limitations.
Ensuring that the Scorpion has completely searched the place is a difficult task with a tele-operated UGV and is wholly dependent on the operator and his support team. Through study it has been determined when employing a UGV in a USAR situation it is preferable to use a two-man team, the second person can focus on search and localisation where the operator may focus more heavily on obstacle avoidance, negotiation and general health of the UGV.

At the end of the scenario time the UGV is recovered to the control station either wirelessly or manually, the Scorpion currently has no technology to recover itself to the start point.

The cameras selected for use on the Scorpion UGV were chosen for their optical performance which includes their automatic or switched adjustment depending on the lighting conditions. Each of the cameras benefit by having IR and white LEDs mounted alongside the camera units, the lights controlled via the control station. The sensors fitted on the Scorpion are able to adequately cope with smoke, dust and mud, as with the remainder of the UGV they are rated IP65.

While not always possible due to the operational situation, the wireless connection is managed by the operator who is trained to avoid total loss of communications. While there is no autonomous recovery there a number of things the operator can attempt to recover communications such as reposition the antenna, move the control station to a new control point, change radio channel, remove/eliminate competing communications.