Redesigning the Emergency Ambulance

Improving Mobile Emergency Healthcare
Project Partners

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Redesigning the Emergency Ambulance
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A report from the Helen Hamlyn Centre for Design and the Department of Vehicle Design at the Royal College of Art in association with the London Ambulance Service, Imperial College Healthcare NHS Trust and the University of the West of England, Bristol.
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Foreword

The interior of a present-day ambulance looks in many ways much as it did when I first started working in the NHS over two decades ago. How we practise pre-hospital and emergency care has, however, changed significantly. Paramedics and ambulance staff now have the skills and technology to better manage the complex needs of patients and treat them where possible in the community rather than at hospital. In London, we have networks of centres that specialise in the care of trauma, stroke and cardiac patients. This means that patients may have to travel further in ambulances to ensure they receive better care. It is therefore essential that we provide an ambulance environment that is more in keeping with the times and facilitates excellent care rather than hinders it.

Funding from the innovation fund at NHS London has given us the support to approach ambulance redesign from a unique multidisciplinary perspective. The design team has done a tremendous job in developing solutions to the problems that ambulance staff face with the current environment in which they work. I would like to thank the project team for their hard work and also the members of the steering group for their support. Staff from London Ambulance Service have been central to the design process, and we hope this work will facilitate the development of an ambulance that is fit for purpose for them and their patients. I would also like to thank Lady Hamlyn for her continuing support of such an important and innovative stream of work.

Lord Ara Darzi of Denham
Executive Summary

This report describes design and development work that has been supported by the Innovation Fund of NHS London and the Helen Hamlyn Trust to redesign the interior of the modern emergency ambulance.

The current interior has emerged piecemeal from a 20th century ambulance that was required to do little more than convey patients to the nearest hospital. Yet the 21st century ambulance service provides both definitive treatment of urgent care conditions at scene and the emergency treatment and transport of seriously ill and injured patients to the centre best suited to their needs. By taking a fresh look at the ambulance interior, we have addressed both of these modern requirements, improving patient care and safety alongside enhanced healthcare efficiency.

The project has built on existing evidence and previous work to address ten improvement areas. It used a process of co-design, in which designers from the Helen Hamlyn Centre for Design worked closely with clinicians from London Ambulance Service and patient representatives, through an iterative process of design, evaluation and modification. During three cycles of testing, ideas were proposed, developed and evaluated. These ideas were then implemented, refined or discarded.

Eight key design innovations emerged from the first round of evaluation, which were further modified and developed during two further iterations. Evidence collected to date, and the final evaluations performed in May 2011, clearly indicate that the new design improves safety and the patient experience, while enhancing the clinical and cost-effectiveness of care. This will yield significant benefits to patients, staff and the NHS as a whole.

This project has created a new and innovative ambulance interior, in response to evidence collected through three research projects since 2005. The purpose-built mobile demonstrator will be used to showcase the project throughout the UK, to build confidence among manufacturers and the wider NHS, with the ultimate aim of progressing to frontline clinical testing and successful implementation into modern emergency care.
The Need for Change

In June 2008 Lord Darzi’s report ‘High quality care for all: NHS Next Stage Review’ outlined plans to create specialised heart, stroke and trauma units. The report also recommended utilising alternative care pathways similar to those provided in community settings, such as urgent care centres and community health teams.

An important and integral component of this community-based approach was an improved mobile healthcare system provided by ambulance services, moving away from the traditional approach of transportation to hospital, in favour of a ‘treat-at-scene-and-refer’ model of healthcare.

The need for change within the Ambulance Service

The Information Centre for Health & Social Care reported that in 2009/10 there were a total of 7.87 million ambulance 999 calls. Approximately 40% did not require treatment in an A&E department, so over three million patients were transported unnecessarily to hospitals in the UK as a result of the lack of alternative methods and/or pathways for treatment. This figure alone illustrates that in order to improve quality, efficiency and cost-effectiveness, they need to change. In recent years this understanding has led to the introduction of a wider range of different, often smaller and less expensive responder vehicles to treat and refer patients where they are (for example at home, school or work). However, the figures cited above suggest that these changes alone have not achieved the ambitions set out in the Darzi review.

In order to effect real change and improvements in care, the ambulance service must be able to bring more of the skills and facilities of the hospital to the patient. This will in turn better enable ambulance staff to deal with those urgent care problems that do not necessarily require a trip to hospital, thereby providing the patient with the ‘right treatment in the right place at the right time’. However, to be successful, these changes in vehicle design and treatment approach will also require better training, in particular increasing the diagnostic skills and knowledge of ambulance clinicians to enable them to treat and discharge patients on-scene. Again, ambulance services in the UK have recognised this need and have responded in part by introducing Emergency Care
Practitioner and more recently the ‘Advanced Paramedic’ or ‘Paramedic Practitioner’ roles.

In parallel, centralisation of specialist heart attack, stroke and trauma services has improved outcomes for those who are treated in these hospitals, but placed an additional burden on ambulance services to transport and provide emergency care to critically ill and injured patients over longer distances in safety. Thus the current ambulance is now called upon both to perform better in these critical roles and to provide effective treatment at-scene to patients with urgent care needs. It was originally designed for neither of these tasks.

**Challenges to change**
These alternative approaches to the delivery of urgent healthcare have presented significant challenges to ambulance services in terms of the types of vehicles required, and the need for additional staff training and operational structures. In 2005 the Government report ‘Taking Healthcare to the Patient’ outlined the case for increasing the range of services available; it described some potential delivery models for these services and also some of the changes required in funding structures and governance. An important aspect of the proposals was the recommendation that a national approach be taken to the procurement of ambulances. It also recognised that, within such an approach, there would be a need to develop delivery models that could provide an effective mix of vehicles, ranging from emergency treatment to urgent services care, and patient transport within the community.

However, the design and development of the equipment and vehicles necessary to support these changes has lagged behind the strategic ambitions of Government, the NHS and ambulance services. The introduction of First Responders, using a range of vehicles, has helped to manage response times and thereby improved efficiency to some extent, but has not as yet led to significant improvements in the quality or cost-effectiveness of ambulance service provision. This is compounded by the fact that ambulance staff do not always have the environment and equipment to provide optimum care according to patient need.

**Real solutions to generate real change**
To address the challenges outlined above, it is necessary to design a 21st century mobile treatment space, which is truly ‘fit for purpose’ and therefore capable of delivering the ‘right treatment, in the right place, at the right time’.

Since 2005, the Helen Hamlyn Centre for Design and the Vehicle Design Department at the Royal College of Art has been working collaboratively with other institutions, including the London Ambulance Service and the University of the West of England, to improve ambulance design. This report describes an innovative approach to the design and development of the emergency ambulance, building on previous successes to produce an ambulance interior that provides better treatment to all patients, matched to their specific healthcare needs, and improves efficiency by transporting only those that require hospital care to the centre best suited to their condition.
Evidence Base

This year-long study was initiated by the NHS National Patient Safety Agency, to investigate how the safety of patients and ambulance staff could be improved through better design of vehicles and equipment. The results contributed to the ongoing national standardisation programme and led to Smart Pods, a project funded by the EPSRC.

2007–2009  **Smart Pods Project**
This two-year research project addressed the whole system of emergency and urgent pre-hospital care. It brought together research by clinicians, designers, social scientists, ergonomists, and operations management analysts, and resulted in a range of innovative propositions that enable clinicians to take healthcare to the community and reduce patient journeys and hospital admissions.

2010–2011  **Our Innovation Proposition:**  
**Redesign of the current A&E ambulance**
This 18-month project has included input from patients, the public, frontline clinical staff, healthcare managers, operational managers, commissioners and purchasers in an intensive co-design and development programme that aims to produce a redesigned A&E ambulance fit for purpose in the 21st Century.
The Design Brief

NHS Regional Innovation Funding
In 2010, this project initiated by the Helen Hamlyn Centre for Design secured funding from the NHS London Regional Innovation Fund (RIF). RIF funding was awarded as part of NHS London’s plans to improve the delivery of local healthcare within the capital. This bid, shortlisted from 133 applications, was one of 16 projects to be supported. The project partners include Imperial College, London Ambulance Service, the Helen Hamlyn Centre for Design and the Vehicle Design Department at the Royal College of Art and the University of the West of England, Bristol. Additional project funding and support has continued to be provided by the Helen Hamlyn Trust. A key component of the project is co-design, whereby the users of the new ambulance interior are an integral part of the design process, and at each stage the design challenges were tested and improved upon through the participation of practising paramedics from the London Ambulance Service and feedback from patient and public representatives.

Will Hancock (CEO South Central Ambulance Service), Steering Group Chair:

‘The innovations emerging from this exciting project have the potential to benefit the safety and clinical care of millions of patients every year who require an emergency ambulance response; ambulance clinicians and their patients have been at the heart of the design process.’

This structured approach has enabled the project to include in the design the ideas and experience of key users, i.e. paramedics and patients, as well as the knowledge and expertise of the designers, to design an ambulance interior fit for purpose in the 21st century.

Service Demand
Each year the demand on ambulance services in the UK increases. In 2009/10, 7.87 million emergency/urgent calls were dealt with – an increase of 391,000 on the previous year. Of emergency calls received, 4.5 million resulted in a patient journey with a cost ranging from £100 to £250 associated with every A&E attendance. Many of these A&E attendances result in a short-stay hospital admission at a cost of £800. There is a need to reduce costs to the NHS by reducing unnecessary attendances at A&E departments and subsequent short-stay admissions to hospital.

There is also an identifiable need for improvement in health and safety standards for both ambulance staff and patients. The National Directors’ Risk, Safety & Governance Group statistics for ambulance services published in October 2010 show that in 2009/10 the overall cost of ambulance service employer liability claims to the NHS was £1,194,615, with frontline ambulance staff constituting 81% of these claims.

Clinical liability claims in 2008/09, for those trusts that submitted data, was £399,043, and statistics show that in 2009/10 clinical claims have increased across all categories; however accurate costings were not given. Categories for clinical claims fell into 5 main categories:

- Patient injury
- Not transported to hospital
- Mis-diagnosis
- Delayed response/conveyance and
- Patient care

Employer liability claims for the 10 ambulance trusts that submitted data were £1.2 million. The highest single
claim was for £200,000 for assault and aggression towards ambulance staff and another single payment of £106,000 was made for equipment failure. These two individual payments represent 26% of total payments made by trusts during 2009/10. Manual handling resulted in 34% of claims with ‘slips, trips and falls’ accounting for 25%.

Project Aims
The overall aim of this project is to build on previous work, using the structured input of stakeholders (ambulance staff and patients) to re-design the interior of the emergency ambulance. The new design is intended to improve patient care and avoid costly and unnecessary journeys to hospital. It will also improve safety by reducing the frequency of adverse incidents that result in either injury or ill health.

We targeted 10 ‘Design Challenge’ areas, identified by previous work, for improvement:

1. **Hygiene and cleanliness** – Improved design will lead to fewer healthcare-acquired infections. Ambulances are prone to getting dirty and contaminated in use. There is a need to create a seamless finish to avoid dirt traps and to simplify the cleaning process. This has the added benefit of making surfaces quicker to clean, so there is less ‘off the road time’ cleaning vehicles. It also reduces the likelihood of infection through contamination.

2. **Patient Experience** – Patient journeys are often stressful events for both the patient and relatives. By addressing issues such as privacy, dignity and comfort of the patient journey, the overall patient experience can be greatly improved. Issues such as poor lighting, heating, vibration and uncomfortable seating need to be addressed. By introducing variable lighting, better temperature control systems, standardised charging points and equipment mounting systems, the patient journey can be greatly improved. This will also improve the working environment of staff and reduce the risk of violence and aggression towards them.

3. **Stock Control** – Improved stock control, using treatment packs tailored for specific clinical procedures, will reduce operational costs and enhance patient care. Presently ambulances are often overstocked by crews – the ‘just in case’ scenario. Modular treatment packs, simply replaced at the end of the shift by ‘make-ready’ staff, will reduce off-the-road-time for restocking. Practitioners will be more aware of stock levels and equipment availability, and the waste caused by carrying unnecessary stock will be reduced, freeing up more space inside the ambulance for the effective delivery of clinical care.

4. **Technology Integration** – Improved technology integration will provide better access to patient records and specialist clinician input. It will also improve communication by establishing robust links to receiving hospitals, through a standard interface used to send patient data instantaneously. This system will not only improve patient care but also reduce medical errors. This does not require new technology developments, simply the integration of what is already available on an ‘off the shelf’ basis, with an element of future-proofing through design and procurement.
5. **Standardisation of equipment** – Often equipment is missing, batteries discharged or spares unavailable. Some equipment is vehicle-specific and therefore not transferrable across the range of ambulance vehicles in service. Standardisation will reduce the number of adverse incidents and equipment failures, and instances of missing or unserviceable equipment. Overall maintenance costs will be reduced and vehicle downtime minimised.

6. **Diagnostics** – Diagnostics and treatment technologies, electronic equipment and user interfaces/displays are currently not standardised. Technology integration will improve communications and the overall efficiency of clinical care provided. Incorporating modern diagnostic technologies, standard interfaces and a single keyboard and screen for data input will reduce medical errors and improve patient care. Ambulance availability will be increased as a result of fewer journeys to A&E. As previously, there is a need to future proof new technology introduction through design and procurement.

7. **‘Future proofing’** – The design needs to accommodate changes in patient care processes and equipment updates. By producing a modular interior, with sections that can be removed and modified as required, standardisation is achieved for box-body and vehicle chassis.

8. **Longevity and carbon footprint** – Both will be enhanced through reduced journeys to A&E. By reducing weight, using a single, moulded interior and by designing for disassembly, and adopting a smaller number of modular treatment packs, significant fuel reductions can be achieved. Other benefits include the ability to recycle parts and materials at the end of the vehicle’s lifetime.

9. **Treatment processes** – These will be facilitated by interior design changes, such as repositioning of the trolley bed for 360° access to the patient. By reconfiguring the interior according to practitioner needs and treatment types, more effective treatment will be delivered on-scene and during transport to specialist centres, leading to earlier interventions. This in turn will reduce patient journeys and hospital admissions, creating a safer environment for both patients and staff.

10. **Functionality** – By providing 360° access to the patient, installing a lay-down space for equipment, and creating easy access to wall-mounted, modular treatment packs and other facilities, the improved design will produce an efficient mobile treatment space and reduce the incidence of healthcare-acquired infections. It will also ensure that treatment is delivered as fast as possible, while minimising the risk of adverse incidents and staff or patient injuries.
Full-size cardboard model of the existing ambulance interior used to understand clinical procedures and ergonomics.

The design team tests and discusses one of the proposed interior layouts.
The Design Process

A number of evaluation outcomes were specified to measure the success of this project:

1. A potential to achieve fewer healthcare-acquired infections (HAIs), measured by a reduction in contamination incidents during scenario-based testing.
2. Fewer adverse incidents and equipment failures, measured by a reduction in treatment time and mitigated clinical incidents during scenario-based testing.
3. Improved patient experience – measured by increased patient ratings.

The team developed a three-dimensional computer-generated design, with visualisations of the production solution, a ‘Working Wall’, ‘fly through’ simulations and full-scale foam model, and used this in an exhibition of the first design iteration. Twenty ambulance staff and four patient representatives took part in this first stage of the co-design process, participating in simulated scenarios and walk-through evaluations.

Clear evidence exists that simulated scenarios can provide a suitable environment for measuring performance in the dynamic surroundings of pre-hospital emergency care. The aim was to investigate the impact of different ambulance environments on the clinical performance of current ambulance staff.

The design team examined how staff undertook the assessment and treatment of two clinical presentations in two environments – an existing frontline London Ambulance Service vehicle, and the ‘new’ prototyped ambulance interior at the Royal College of Art.

Testing different treatment pack configurations and placements
Crews prepare to perform management of a simulated cardiac arrest scenario using an ambulance test rig.

A UV light is shone over a paramedic’s hands to look for contamination spread during the clinical scenarios.
Testing the Design

Sixteen ambulance staff – eight double crews, each crew including at least one paramedic, were rated by two independent observers using video-recording and checklists. The crews were asked to manage two simulated and standardised emergency scenarios:

**Scenario 1** – The management of a cardiac arrest, using a ‘Sim Man’ (Laerdal) high-fidelity patient simulator

**Scenario 2** – A contamination scenario, using a trained simulated patient/actor with a simulated bleeding leg ulcer infected with MRSA

Each group took part in these simulation exercises on different days, and both the existing front-line ambulance and the prototyped ambulance were utilised.

These simulated sessions were videotaped, using remote-control cameras, and both technical and nontechnical skills were assessed by two independent observers, using pre-defined checklists and rating scales. The cardiac scenario was rated on technical skills using the Resuscitation Council (UK) Guidelines. In the contamination scenario the team used an invisible contaminant, only detectable under ultraviolet light, and charted the potential and actual spread of contamination after each scenario.
There was a substantial difference in the time taken to complete the wound dressing between the conventional ambulance and the new design. The average (median) time required was 5 minutes 30 seconds to complete the wound dressing in the conventional ambulance, compared to 2 minutes 45 seconds in the new design. This difference is largely due to the time taken to access treatment consumables in the conventional ambulance, compared to the treatment packs in the new design. Staff comments indicated that in the conventional ambulance there is a sense of frustration with layout and ease of access to equipment when it is needed:

‘Too many different layouts in the different ambulances, making treatment more difficult than is necessary. The equipment is in the wrong place; everything we need to do means bending over the patient – bending over the patient to dispose of soiled items in the bins and things dropping out of the cupboards onto the patient.’

Other differences, such as time taken to move the patient to the bed and to measure blood pressure, were not significant on statistical testing.

There were some significant differences in contamination incidents between the two designs. Potential contamination incidents captured on video were much higher in the conventional ambulance compared to the new design (6.5 versus 2.0). There were smaller differences in the actual areas of contamination identified using a UV light in both designs. This indicates that improved design has minimised the potential for contamination. However, staff still need to ensure that they follow good infection control procedures (e.g., hand cleaning and safe disposal of waste) to prevent

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**Figure 1: Median number of seconds taken to complete task in wound dressing scenario**

**Figure 2: Median number of contamination episodes in wound dressing scenario**
the spread of contamination and the risk of healthcare-acquired infection. The addition of a hand-cleaning area next to the head of the patient stretcher, coupled with an increased awareness of infection control, will lead to even fewer contamination incidents in future.

The new ambulance design achieved small improvements in performance scores during this scenario. Currently, ambulance staff are accustomed to using their personal equipment bag to perform advanced life-support in the ambulance. In the new design there is no need to use a personal bag inside the vehicle, because all the equipment necessary for advanced life-support has been placed in a designated resuscitation drawer in the ambulance.

Results of Feedback and Thematic Analysis (Round One)
Ambulance staff and patients were also asked to evaluate both the old and the new treatment environments, using a Likert scale with ratings from 1 (worst) to 5 (best) and an additional ‘no opinion’ option.

The first feasibility study conducted in October 2010 gave a baseline for further studies later in the project. The new design differed significantly from the conventional emergency ambulance in 11 key areas. Additions to the ambulance included:

- Hand washing facilities
- Fold-away work surface
- Resuscitation drawer
- Modular treatment packs
- Integrated technology
- Mobile monitoring
- Patient stretcher repositioned to the centre of the ambulance treatment space
- Removal/repositioning of front passenger seat
- Access to carry chair from outside the vehicle
- Repositioning of passenger seats
- Introduction of a side-loading option

Patient:
'I have taken part in this project because I would like to help improve the ambulance design and help others to have a better experience with their ambulance travel. Co-design is very important.'

Staff:
'To assist in improving the design of the ambulance and make the working lives of road staff more comfortable and less stressful.'
The results from the first round of evaluation are shown in the following table.

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<tr>
<th>Design Issue</th>
<th>Paramedic Response (Scenarios)</th>
<th>Paramedic Response (Other)</th>
<th>Patient Response</th>
<th>Issues Raised</th>
<th>Design Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand washing facilities</td>
<td>62% – very good/fairly good idea</td>
<td>60% – very good/fairly good idea</td>
<td>100% – very good idea</td>
<td>Infection control – changing water, cleaning etc</td>
<td>Removal of sink and replacement with hand-cleansing area</td>
</tr>
<tr>
<td>Repositioning of stretcher to centre of vehicle</td>
<td>100% – new position has made treatment process very easy/fairly easy</td>
<td>100% – new position has made treatment process very easy/fairly easy</td>
<td>100% – good idea</td>
<td>Facilities for bariatric patients</td>
<td>Find bariatric stretcher</td>
</tr>
<tr>
<td>Removal of front passenger seat</td>
<td>57% – good/fairly good idea</td>
<td>80% – good/fairly good idea</td>
<td>N/A</td>
<td>Infection control issues. Paramedic concerns re: impact on existing working practices</td>
<td>Redesign with front seat returned to usual position in front of vehicle</td>
</tr>
<tr>
<td>Fold-away work surface</td>
<td>50% – very/fairly helpful</td>
<td>80% – very/fairly helpful</td>
<td>N/A</td>
<td>It needs to be repositioned further down the vehicle. It needs to be made bigger so it can accommodate drug packs. It is ideal for extra monitoring equipment during patient transfers. Good for infection control</td>
<td>Reposition and resize</td>
</tr>
<tr>
<td>Treatment packs</td>
<td>81% – very/fairly helpful</td>
<td>80% – very/fairly helpful</td>
<td>N/A</td>
<td>Packs need to be made out of 'see through' material, clearly labelled. Need to be hard plastic cases, easily cleaned</td>
<td>Consider use of different materials</td>
</tr>
<tr>
<td>Resuscitation drawer</td>
<td>75% – a lot/bit easier</td>
<td>100% – a lot/bit easier</td>
<td>N/A</td>
<td>Use of drawer dividers to keep everything neat and tidy. Position at seat height to minimise bending</td>
<td>Utilise drawer dividers. Deeper drawer to store all of the required equipment</td>
</tr>
<tr>
<td>Mobile monitoring system</td>
<td>88% – very good/fairly good idea</td>
<td>100% – very good/fairly good idea</td>
<td>N/A</td>
<td>Good idea, access to screen 360°. Needs to be movable to keep cables out of the way, less tangled. Cleaning – both screen and tracking system</td>
<td>Ensure tracking system is easily cleaned</td>
</tr>
<tr>
<td>Integrated technology</td>
<td>81% – very good/fairly good idea</td>
<td>80% – very good/fairly good idea</td>
<td>N/A</td>
<td>Can be used to get clinical advice from doctor. Hospital resus department will get correct information. Alerting the hospital must be improved as it involves the driver using the radio with a hand-written message on a dirty glove. Direct communication with hospital would be much better</td>
<td>Need to look at functionalities of the technology to ensure it is fit for purpose</td>
</tr>
<tr>
<td>Side loading</td>
<td>82% – bad/fairly bad idea</td>
<td>80% – bad idea</td>
<td>75% -very good/fairly good idea</td>
<td>Difficulty loading/unloading due to complex nature of street furniture and narrow streets. Hospital bays would not be able to accommodate this type of loading system</td>
<td>Redesign and go back to conventional rear loading system</td>
</tr>
<tr>
<td>Design Issue</td>
<td>Paramedic Response (Scenarios)</td>
<td>Paramedic Response (Other)</td>
<td>Patient Response</td>
<td>Issues Raised</td>
<td>Design Response</td>
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<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
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<tr>
<td>Outside/inside access to carry chair</td>
<td>94% – very good/fairly good</td>
<td>100% – very good idea</td>
<td>N/A</td>
<td>All lifting and manual handling equipment should be in one place. Saves a lot of moving in/out of the ambulance and gives easy access. Should have happened a long time ago. Always difficult getting chair out, particularly when in a hurry.</td>
<td>Move all moving and handling equipment to one cupboard for easier access</td>
</tr>
<tr>
<td>Repositioning of rear passenger seats</td>
<td>68% – very good/fairly good</td>
<td>40% – very good/fairly good</td>
<td>100% – very good idea</td>
<td>Keeps passengers away from working area. Better for relatives. Good idea: gives enough space between you and the patient’s carer or loved one.</td>
<td>Keep seats at the rear but reposition due to back loading design change</td>
</tr>
<tr>
<td>Safety of passengers when being loaded/unloaded</td>
<td>37.5% – fairly unsafe 6.25% – very unsafe</td>
<td>60% – fairly unsafe 25% – fairly safe</td>
<td>75% – very safe</td>
<td>There is a need for more space for wheelchair users. Facility to keep the wheelchair on board with the patient in it rather than transfer onto the seat on board</td>
<td>Investigate measures to secure wheelchairs with patient still in situ</td>
</tr>
<tr>
<td>Seating comfort</td>
<td>N/A</td>
<td>N/A</td>
<td>50% – very comfortable, 50% – comfortable</td>
<td>Perhaps the seats could be a little softer. The evaluation may be slightly different in a moving vehicle</td>
<td>Look at materials to enhance cushioning of seating</td>
</tr>
<tr>
<td>Atmosphere inside new vehicle</td>
<td>N/A</td>
<td>N/A</td>
<td>100% – very positive</td>
<td>There could be some encouragement for children to help keep them calm: perhaps some cartoons/animations on one wall</td>
<td>No action points</td>
</tr>
<tr>
<td>Privacy</td>
<td>N/A</td>
<td>N/A</td>
<td>100% – very good</td>
<td>Privacy is much improved in this ambulance</td>
<td>No action points</td>
</tr>
<tr>
<td>Artificial lighting</td>
<td>N/A</td>
<td>N/A</td>
<td>100% – very good</td>
<td>No comments made</td>
<td>No action points</td>
</tr>
<tr>
<td>Interior tidiness</td>
<td>N/A</td>
<td>N/A</td>
<td>75% – very tidy/fairly tidy</td>
<td>Storage of items in the equipment lockers: please consider how items could be stored more efficiently and for access and usability</td>
<td>More efficient use of storage space: treatment packs on display rather than in cupboards</td>
</tr>
<tr>
<td>Overall rating of new design</td>
<td>12.5% – excellent 75% – good 60% – good 40% – OK</td>
<td>100% – excellent</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Computer generated renderings of a side-loading ambulance concept
Design Issues

Side loader design
Patients’ representatives were asked similar questions to the ambulance crews but, in addition, they were asked a slightly modified set of questions, addressing issues such as overall atmosphere, seating comfort, tidiness and privacy.

It was clear from the results obtained that the side-loading concept was the least popular, with 82% of ambulance staff responses rating this as a very bad or fairly bad idea. Thematic analysis showed that there were practical considerations that made this design modification the least likely to succeed.

Most comments centred around issues of parking and loading/unloading. Most felt that it would make loading/unloading difficult in urban areas, due to street furniture and narrow streets, and that it would encounter problems at hospitals, where loading bays precluded the use of side-loading.

Patient representatives had a slightly different view of the side-loader and felt that overall it was a safer way to be loaded into an ambulance. However, they also recognised that there were practical considerations to be taken into account with this design, and accepted that it was not a popular choice for staff.

Passenger seats
Issues around removal of the front passenger seat focused on infection control and safe working practices, with 57% of staff stating that it was a bad idea. Objections raised centred on already established working practices, such as giving directions and assistance when driving and being able to discuss patient care while sitting beside each other.

Stretcher relocation
The most popular change, with a 100% positive response, was the repositioning of the stretcher into the middle of the vehicle. Evaluation comments ranged from ‘Excellent to have all-round access to the patient for cannulation and general patient care’ to ‘After dealing with the patient in the centre I can’t imagine doing it any other way’. Most felt that it gave much greater flexibility when treating patients.
Design Changes

Eight design changes resulted from our first set of feasibility tests. These changes were made after feedback from both staff and patients and by studying the data collected during scenario testing.

- Revert to rear tail lift – wider access at rear can now accommodate bariatric stretcher and wheelchairs
- Addition of bariatric stretcher
- Lay-down surface repositioned and widened
- Passenger seats repositioned to accommodate redesign of tail lift
- Treatment packs changed from soft to hard case material
- Sink removed and hand cleaning station added
- Work station/monitor moved to the opposite side of the ambulance – to previous position of wash sink
- All patient handling and moving equipment placed in one cupboard, along with the carry chair, and made accessible from outside as well as inside the vehicle

Exhibition held at the Royal College of Art in September 2010 where the first iteration of the redesigned ambulance was shown
Scenario Testing (Round Two)

Results of Testing Feedback and Thematic Analysis
In December 2010 a second evaluation was conducted on the new vehicle design, incorporating the eight modifications that resulted from the initial test results. The design team was unable to scenario-test certain design features until a later stage, when the fully working demonstrator became available. However, patients and staff were asked to assess all design features, both already realised and proposed.

The following five design changes were constructed and tested during the round two evaluation:

1. Bariatric Stretcher
2. Lay-down surface repositioned and widened
3. Passenger seats repositioned
4. Hard-case treatment packs
5. Sink area modified to include hand-cleaning area

The following three changes were proposed but not formally tested during the round two evaluation:

1. Rear tail-lift
2. Work station/monitor moved to the opposite side of the ambulance – to previous position of wash sink
3. All patient handling and moving equipment placed in one cupboard, and made accessible from outside as well as inside the vehicle
## Results from the second round of evaluation. *(All actual changes in italics)*

<table>
<thead>
<tr>
<th>Design Issue</th>
<th>Paramedic Response (Scenarios)</th>
<th>Paramedic Response (Other)</th>
<th>Patient Response</th>
<th>Issues Raised</th>
<th>Design Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand cleaning area</td>
<td>62% – very good/fairly good idea</td>
<td>77% – very good/fairly good idea</td>
<td>N/A</td>
<td>Having easy access to hand cleansing facilities is a good idea.</td>
<td>No action points</td>
</tr>
<tr>
<td>Position of stretcher in centre of vehicle and ease of use</td>
<td>87% – new position has made treatment process very easy/ fairly easy</td>
<td>75% – new position has made treatment process very easy/ fairly easy</td>
<td>100% – feels very safe</td>
<td>Looks good but trolley bed needs to be height-adjustable when locked in position</td>
<td>No action points</td>
</tr>
<tr>
<td>Bariatric stretcher</td>
<td>100% – good/fairly good idea</td>
<td>100% – good/fairly good idea</td>
<td>100% very good idea</td>
<td>Lots of large patients struggle on our small stretchers at the moment. A long time coming. Could an extension be developed to allow tall patients to lie on the bed without overhanging the end?</td>
<td>No action points</td>
</tr>
<tr>
<td>Repositioned/widened lay down surface</td>
<td>87% – very/fairly good idea</td>
<td>75% – very/fairly good idea</td>
<td>N/A</td>
<td>Could a tray for cannulation kit be incorporated? Require similar surface on other side of the vehicle as well to avoid stretching across patient and trolley bed. Easy to access</td>
<td>No action points</td>
</tr>
<tr>
<td>Hard case Treatment Packs</td>
<td>87% – very/fairly good idea</td>
<td>100% – very/fairly good idea</td>
<td>N/A</td>
<td>You need something strong and easy cleaning. The lighter the better. Ideal if they were transparent material</td>
<td>No action points</td>
</tr>
<tr>
<td>Redesigned resuscitation drawer</td>
<td>88% – very/fairly good idea</td>
<td>75% – very/fairly good idea</td>
<td>N/A</td>
<td>Would be useful for driver to access observations in cab if passing a priority call. Needs to be movable in all directions like an ‘anglepoise’ lamp. The height is an issue for me as I am small. If it could be lowered when necessary that would be perfect</td>
<td>Driver access to integrated technology. Address height issues.</td>
</tr>
<tr>
<td>Mobile Monitoring System</td>
<td>87% – very good/fairly good idea</td>
<td>75% – very good idea</td>
<td>N/A</td>
<td>There is now much emphasis within the NHS ambulance service on alternative care pathways. These are often specific to local areas so crews may be unfamiliar with them. It would be useful to have access, when attending each job, to local care pathways and be able to drill down to the relevant referral guidelines. Would be useful to have access to certain internet sites. Useful to have direct contact with clinical coordination desk. Saves a lot of time; staff are more aware of the patient’s current position. Concern re: monitor position and crew height – possibility of accidental breakage. The computer and additional screens are an excellent idea. Technology alert to hospital fantastic idea! Good to have blue button on monitoring equipment and automatic send to receiving hospital</td>
<td>Ensure functionality of technology is as broad as possible.</td>
</tr>
<tr>
<td>Integrated Technology</td>
<td>81% – very good/fairly good idea</td>
<td>100% – very good/fairly good idea</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Issue</td>
<td>Paramedic Response (Scenarios)</td>
<td>Paramedic Response (Other)</td>
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</tr>
<tr>
<td>Rear loading tail lift</td>
<td>87% – good/fairly good idea</td>
<td>100% – good/fairly good idea</td>
<td>100% – very safe for patients</td>
<td>Side-loading impractical in narrow streets. Definitely a plus. Side-loading is the most attractive but operational constraints are fully accepted</td>
<td>No action points</td>
</tr>
<tr>
<td>Moving and handling equipment in same cupboard, accessible from inside and outside vehicle</td>
<td>100% – very good/fairly good idea</td>
<td>100% – very good idea</td>
<td>N/A</td>
<td>Good to keep it all together. Easy to access. Great. Saves a lot of time if the equipment is stored in the right place</td>
<td>No action points</td>
</tr>
<tr>
<td>Repositioning of rear passenger seats</td>
<td>50% – very good/fairly good idea</td>
<td>50% – fairly good</td>
<td>100% – very safe</td>
<td>You are able to have eye-to-eye contact with the passenger if the patient is unable to answer questions for themselves. Having a seat so close to the back could be very dangerous if the vehicle was to be hit from behind; also having the only other exit door at the back so close together could be a problem if there was an accident. Good to have seats at the back, but safety might be an issue.</td>
<td>No action points</td>
</tr>
<tr>
<td>Safety of passengers when being loaded/unloaded</td>
<td>9% – very safe</td>
<td>75% – neither safe nor unsafe</td>
<td>100% – very safe</td>
<td>Thank you for changing the side loading. I did liaise with other LAS people and patients and they agree with your new changes. This is what co-design is all about – great.</td>
<td>No action points</td>
</tr>
<tr>
<td>Overall Rating of New Design</td>
<td>37% – excellent</td>
<td>60% – good</td>
<td>25% – excellent</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50% – good</td>
<td>40% – OK</td>
<td>75% – good</td>
<td></td>
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</tr>
</tbody>
</table>
The third and final round of iterative evaluation took place in May 2011 in a purpose-built mobile demonstrator model. This was the final stage of testing and feedback, before engaging NHS and industry partners with a view to building and road testing a working prototype of the new ambulance.

The design team analysed the results from the second evaluation and addressed the issues that both the patients and paramedics had raised. Most of the work was aimed towards refining the ideas already tested during December and finalising the design details.

The ambulance demonstrator was tested by ambulance crews on the two scenarios - infection control and cardiac arrest - during May 2011.
Results from the third round of evaluation.

<table>
<thead>
<tr>
<th>Design Issue</th>
<th>Paramedic Response (Scenarios)</th>
<th>Paramedic Response (Other)</th>
<th>Patient Response</th>
<th>Issues Raised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulance interior cleanliness</td>
<td>67% – very clean</td>
<td>100% – very clean / fairly clean</td>
<td>N/A</td>
<td>Excellent hygiene and infection control, far better than current vehicles</td>
</tr>
<tr>
<td>Ease of addressing infection control issues</td>
<td>67% – fairly easy</td>
<td>50% – fairly easy</td>
<td>N/A</td>
<td>Perhaps there should be a bin on both sides of the vehicle</td>
</tr>
<tr>
<td>Hand cleaning facilities</td>
<td>100% – very good/fairly good</td>
<td>50% - fairly good</td>
<td>100% very / fairly good</td>
<td>Cleansing area not big enough Not big enough but in the right position. The use of soap and water would be more ideal The cleaning station is a little cluttered</td>
</tr>
<tr>
<td>Ease of keeping ambulance clean during operation</td>
<td>83% – very/fairly easy</td>
<td>50% – very easy</td>
<td>75% - very / fairly easy</td>
<td>The surfaces are all flat and look easy enough to wipe over</td>
</tr>
<tr>
<td>Access to equipment and consumables</td>
<td>50% – very easy</td>
<td>100% – fairly easy</td>
<td>N/A</td>
<td>The packs of equipment area a very good idea. Love the resuscitation drawer but will paramedics have to sign for 2 drug packs?</td>
</tr>
<tr>
<td>Ease of inspection and stock control</td>
<td>50% – very easy</td>
<td>100% – fairly easy</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Mobile monitoring system</td>
<td>88% – very good/fairly good idea</td>
<td>100% – very good/fairly good idea</td>
<td>N/A</td>
<td>Include a com link to the driver and radio system. I like the swivel function of the screen, the visual display and user function. V. Good. The O2, BP, Defib wire may need pouching to stop it falling down or on retractable wiring (this may break easily). Pouches easier [hard pouches] The mechanism for securing it at different angles needs to be user defined, eg. tightness level, if it was manufactured it would become loose over time</td>
</tr>
<tr>
<td>Ease of delivering efficient patient care</td>
<td>100% - very easy / fairly easy</td>
<td>100% very easy / fairly easy</td>
<td>N/A</td>
<td>Add a roof mounted and folding rail that can be used to attach medical pumps etc</td>
</tr>
<tr>
<td>Patient’s perception of safety using the tail lift</td>
<td>33% - very safe</td>
<td>100% - very safe</td>
<td>50% very / fairly safe</td>
<td>Needs a wide tail lift to accommodate wheelchairs As long as the tail lift is wide enough for wheelchair users then it is a good idea</td>
</tr>
<tr>
<td>Ease of access to carry chair</td>
<td>100% - very easy</td>
<td>100% - very easy</td>
<td>N/A</td>
<td>Good to have access from outside and inside especially in the winter when all the heat escapes.</td>
</tr>
<tr>
<td>Stretcher position</td>
<td>100% - very good</td>
<td>100% - very good</td>
<td>100% - very good</td>
<td>The stretcher position is good, easy IV access. Need to address locking mechanism in the floor Good as paramedic is able to move around it, also gives better access if two people are dealing with the patient</td>
</tr>
<tr>
<td>Safety of seating arrangements</td>
<td>83% – very / fairly safe</td>
<td>100% – very / fairly safe</td>
<td>50% - fairly safe</td>
<td>Seats look fairly safe based on looking at them, again unable to properly assess</td>
</tr>
<tr>
<td>Ease of use of monitoring equipment</td>
<td>100% - very / fairly good</td>
<td>100% - very good</td>
<td>N/A</td>
<td>All monitoring equipment looks like it is in a suitable position Can it be replaced? Is it easy and cheap?</td>
</tr>
<tr>
<td>Use of technology improving patient care</td>
<td>83% - very / fairly good</td>
<td>100% - very / fairly good</td>
<td>N/A</td>
<td>Can we rely on it. We need good reliable software Could this system incorporate telemetry so the receiving hospital can see the ECG rhythm</td>
</tr>
<tr>
<td>Design Issue</td>
<td>Paramedic Response (Scenarios)</td>
<td>Paramedic Response (Other)</td>
<td>Patient Response</td>
<td>Issues Raised</td>
</tr>
<tr>
<td>------------------------------------</td>
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<td>------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Laydown surface position</td>
<td>50% - very / fairly good 33% - neither</td>
<td>50% - fairly good 50% - neither</td>
<td>N/A</td>
<td>It restricts staff to one sided use and may cause leaning over the patient, a clip on the rail of the trolley bed may be more suitable with a wipe clean surface. This surface should be near the head end to enable intubation equipment to be laid out in full.</td>
</tr>
<tr>
<td>Treatment packs position</td>
<td>100% - very / fairly good</td>
<td>50% - very good 50% - neither</td>
<td>N/A</td>
<td>They are a good idea – easy option for restocking.</td>
</tr>
<tr>
<td>Resuscitation drawer</td>
<td>100% - very / fairly good</td>
<td>100% - very / fairly good</td>
<td>N/A</td>
<td>The drawers are not big enough, need to be deeper. Risk of catching fingers if both drawers are open. Of all the improvements I believe this addition is the best. Some thought needs to be put into the interior layout of the drawer – a formalised layout.</td>
</tr>
<tr>
<td>Tail lift</td>
<td>67% - very good</td>
<td>50% - very good 50% - very good</td>
<td>N/A</td>
<td>Needs a wide tail lift to accommodate wheelchairs. As long as the tail lift is wide enough for wheelchair users then it is a good idea. Back loading is better for wheelchairs.</td>
</tr>
<tr>
<td>Bariatric stretcher capability</td>
<td>100% - very / fairly good</td>
<td>100% - very good 100% - very good</td>
<td>N/A</td>
<td>Very good idea as the population is getting larger and there is a shortage of bariatric ambulances.</td>
</tr>
<tr>
<td>Moving and handling equipment</td>
<td>100% - very good</td>
<td>100% - very good</td>
<td>N/A</td>
<td>Great idea – especially when all the lifting and handling gear is all in one place.</td>
</tr>
<tr>
<td>Repositioning of rear passenger seats</td>
<td>16% – very good/fairly good idea 67% - neither</td>
<td>100% – very good/fairly good</td>
<td>100% very / fairly good</td>
<td>Folding seats are a very good idea, more space for working and easier to mop. Extremely important that crews are able to exit the vehicle in cases of aggressive patients or relatives so the seating arrangements are better than the current vehicle. Is it possible for a relative to hold the patient’s hand en route or not?</td>
</tr>
<tr>
<td>Safety of passengers when being loaded/unloaded</td>
<td>37.5% – fairly unsafe 6.25% – very unsafe</td>
<td>60% – fairly unsafe</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Seating comfort</td>
<td>N/A</td>
<td>N/A</td>
<td>50% very / fairly comfortable</td>
<td>Looks as if it could be functional but as a prototype can’t assess comfort of the seats. Chairs look good, good colour but unable to test as not functioning.</td>
</tr>
<tr>
<td>Atmosphere inside new vehicle</td>
<td>N/A</td>
<td>N/A</td>
<td>100% very / fairly positive</td>
<td>N/A</td>
</tr>
<tr>
<td>Privacy</td>
<td>N/A</td>
<td>N/A</td>
<td>75% - very / fairly good</td>
<td>Transitional glass would be nice. Windows are great but need to address privacy especially at night when light is on. Given the life span of ambulance the elimination of transitional glass could be a false economy.</td>
</tr>
<tr>
<td>Artificial lighting</td>
<td>N/A</td>
<td>N/A</td>
<td>100% very / fairly good</td>
<td>N/A</td>
</tr>
<tr>
<td>Interior tidiness</td>
<td>N/A</td>
<td>N/A</td>
<td>75% - very tidy</td>
<td>The appearance is very good and clean looking, looks neat and tidy and easy to clean. The absence of the provision for a deep clean on each shift – hand steam cleaner could be provided is inexplicable. Paper towel cleaning belongs in the Ark. Infection control is something that needs staff action as the vehicle alone cannot control it.</td>
</tr>
<tr>
<td>Overall rating of new design</td>
<td>17% – excellent 83% – good</td>
<td>50% – excellent 50% – good 25% – excellent</td>
<td>75% – good</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Next Steps

The design team now aims to proceed to clinical trials of the new design working with real patients and NHS settings before widespread implementation. This will further demonstrate the clinical and cost-effectiveness of the new design, and its potential to substantially improve the delivery of urgent and emergency healthcare.

With the ongoing support of our project sponsors, Steering Group, healthcare and industry partners, we look forward to making our newly designed, extensively tested, and truly innovative ambulance interior a reality in the modern NHS.
The images shown here reflect the development of the project from sketch and cardboard modelling to computer simulations and the fitting out of a mobile demonstrator unit.
Further Reading


National Directors Risk, Safety & Governance Group, Supporting paper. 12 August 2010 National Governance Workstream Benchmarking Project

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