REDESIGNING THE AIR AMBULANCE

Redesigning the Air Ambulance Interior is a design research project, which uses the process of co-designing with medical flight crew from a level 1 trauma center in the US, to envision an Air Ambulance interior for inter-hospital transfers in the 21st century. The redesigned interior utilizes the five design dualities surfaced from the co-design process to enable the medical flight crew enhanced access to their patient, medication, and equipment. Ultimately, this leads to an improvement in the inter-hospital transfer experience for the medical crew.
With hospitals forming integrated networks, which include specialized hospitals with expertise in specific diseases / injuries, patients at other hospitals within the network can access these specialized hospitals through inter-hospital transfers, resulting in better patient outcomes. Usage of inter-hospital transfers has also increased due to a greying population that requires the additional diagnostics or therapeutic interventions. However, the commonly used EC135 Air Ambulance interior (60% of Air Ambulance rides in the US) has remained largely unchanged despite numerous changes in protocol, procedures and policies for inter-hospital transfers.

**GROUND AMBULANCE**
80% of all rides

**AIR AMBULANCE**
20% of all rides

“Dedicated medical helicopters are mobile flying emergency intensive care units deployed at a moment’s notice to patients whose lives depend on rapid care and transport.”

“Those transported by air had a 2 day decrease in hospital length of stay.”

“Low incidence of adverse events during air medical transport.”

“Reduced ‘out-of-hospital’ time for critical patients with reduction of 20-100 mins.”

“Experience dealing with critically ill and injured patients.”

Resulting in dramatic increase from 200,000 rides in 1999 to 400,000 rides in 2012 with 70% of rides for inter-hospital transfers.

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Snapshot of the interior seems almost contradictory to the literature.
To unravel the complex nature of inter-hospital transfers, two flight paramedics and a flight nurse were recruited into the study by the researcher as co-designers from early research till the final concept. Numerous design methods were used to learn, collaborate, and solicit feedback. This enabled the researcher to empathize with the medical flight crew, learn from their experiences, and focus on a solution that was implementable within 5-8 years.

List of design methods

1. Literature Review
2. Shadowing
3. Contextual Inquiry
4. Postcard Surveys
5. Business Origami
6. Work inventory
7. User Journey Map
8. Card Sorting
9. Touchstone tour
10. User testing

1 Universal Methods of Design (2012)
Design method 1:
CONTEXTUAL INQUIRY

In the early phase of this project, priority was given to understand the work of the medical crew and gauge the impact and influence of the physical environment on their work.

A pilot, an aircraft technician, 3 flight paramedics, and 3 flight nurses were interviewed to understand their goals, tasks, and frustrations.

The medical flight crew surfaced numerous deep frustrations with the space.

Early findings

It was surprising to learn that the layout of Air Ambulances was distinctly different, which caused confusion when the spare helicopter needed to be used. The layout between the Air Ambulance and the Ground Ambulance is also different, thus forcing the medical crew to learn two entirely different systems.
Design method 2:
BUSINESS ORIGAMI

A physical representation of the scenario of an inter-hospital transfer was built with the flight crew to explicitly show the roles of people, objects, and environments at different stages.

Learning points:
Roles and responsibilities

There are 3 distinct roles.

• Primary provider: the ‘brains’ of the operation who directs the care of the patient during transport and serves as the navigator in front when travelling to receive the patient.

• Secondary provider: the ‘hands’ of the operation who executes the protocols proposed by the primary provider.

• Pilot: the navigator and operator of the helicopter.
INTER-HOSPITAL TRANSFER PROCESS

RECEIVE THE CALL
- Receiving Doctor
- Dispatcher
- Transferring Doctor

PREPARE FOR FLIGHT TO DESTINATION
- Pilot
- Primary Provider
- Secondary Provider
- Helipad

MOVE OUT OF THE HELICOPTER
- Primary Provider
- Secondary Provider
- Stretcher
- Primary Bag
- Cardiac Monitor
- Outlying Hospital

FLY TO DESTINATION
- Pilot
- Primary Provider
- Secondary Provider
- Outlying
- Helicopter

RECEIVE AND STABILIZE PATIENT AT DESTINATION
- Primary Provider
- Secondary Provider
- Emergency Nurse
- Patient
- Primary Bag
- Cardiac Monitor
- Outlying Hospital

TRANSFER PATIENT INTO THE HELICOPTER
- Pilot
- Primary Provider
- Secondary Provider
- Patient
- Primary Bag
- Cardiac Monitor
- Helipad

LAND AND TRANSFER PATIENT OUT OF THE HELICOPTER
- Primary Provider
- Secondary Provider
- Patient
- Primary Bag
- Cardiac Monitor
- Helipad

FLY BACK TO HOSPITAL
- Pilot
- Primary Provider
- Secondary Provider
- Patient
- Primary Bag
- Cardiac Monitor
- Helipad

MOVE PATIENT ONTO HOSPITAL BED
- Primary Provider
- Secondary Provider
- Receiving Nurse
- Patient
- Receiving Hospital

STERILIZE EQUIPMENT & REFUEL
- Pilot
- Primary Provider
- Secondary Provider
- Helicopter

START

END

User Journey Map

Design method 3:
USER JOURNEY MAP

Using the learning points from the business origami method, a visualization of the story about the crew’s actions, feelings, and perceptions was created.

Learning points:
Most intense stage

‘Flying back to hospital’ was unanimously agreed to be the most intense stage. It was the only time when the crew was solely responsible for the patient and they could not call on other hospital personnel for assistance.

Secondary provider’s nightmare

As the role of the secondary provider is to execute the directive of the primary provider, the care of the patient falls entirely on the secondary provider. Thus, placing undue stress on the secondary provider.
Design method 4: TOUCHSTONE TOUR

A mannequin was used as a touchstone for questions and insight. Simulation of procedures with think-aloud protocols using the actual medical equipment was done. The researcher video-recorded it to learn the complex descriptions of the procedures and to overcome the HIPAA regulations which prevented the recording of actual patients.

Learning points: Dangerous Practices

When everything was set in place, the secondary provider only had upper body access to the patient and the primary provider could not reach needed equipment. The crew was forced to unbelt themselves to extend their reach. Thus, placing themselves in danger.

Patient as equipment tray

Patients in the Air Ambulance require substantial equipment and with no elegant solution to hold the equipment and still allow access to the patient, a large portion of the equipment were placed on the patient.
Design method 5: SHADOWING

In order to gain insight into the crew’s activities and decision patterns, the researcher shadowed the medical flight crew for three shifts of 12 hours for a total of 36 hours.

Learning points: Stressful environment

Due to the noise caused by the blades and the vibration, the helicopter creates anxiety in people. The limited and chaotic space escalates unnecessary stress on the crew.

Space blindness

The pilot is blocked off from the medical crew with a full height divider placed behind the pilot’s seat. When alarms went off behind, it proved limiting as the crew had to split their attention tending to the patient and explaining to the pilot.

Helmet deafness

The diagnostic equipment alarms are not connected to the helmet speakers. With the noise of the helicopter, it was an acquired skill to know which alarm belonged to which equipment.
Design method 6: POSTCARD SURVEYS

Surveys were given out to the crew to self-report their thoughts, attitudes, feelings, characteristics, or perceptions so as to understand the crew and their group dynamics.

Learning points: Bonding over experiences

Working together in such intense situations made the crew very close to one another. They served as each other’s pillar of support especially if they worked on a case that triggered an emotional response.

Relationships as leverage

The view that their crew was like their family was consistent across the participants. With such a strong sense of camaderie, it seemed imperative to ensure the helicopter interior encouraged providers to help each other for difficult transfers or situations.
ACCESSIBILITY ISSUES

Movable seat’s immobility

The secondary provider’s seat is able to rotate and translate to access the patient. However, the controls of the seat were confusing and the movement was also stiff. It required both medical crew to move. Most of the crew were unable to demonstrate how to move the seat. Thus, the seat usually remained stationary.

Awkward body angles

As the seat was bulky, the provider could only rotate the seat slightly before it hit the stretcher or wall leaving the secondary provider at an awkward angle to the patient. This made it challenging to access the patient when giving injections & adjusting equipment.

The secondary provider also had to contort to uncomfortable positions to reach some equipment as they were placed in positions that did not take into account how the medical procedure was done.
PRECISION ISSUES

Tedious IV tubing tracking

Medical crew waste precious time tracking the tubing to precisely find the correct IV port to inject medication. Patients in the Air Ambulance usually need at least 1 IV bag and 2-3 medication bags causing the tubing to entangle easily.

Color does not distinguish

The equipment are placed in bags that fit its size and do not follow organizing principles. It is possible to have same colored bags for different treatments, making it an acquired skill to precisely pick what you need. Compounding the complexity is the difference in color coding for ground ambulances.

Stuff everywhere

As the treatment bag has lots of equipment crammed in, it bursts when unzipped. In situations where seconds matter, the flight crew would pull everything out to get what they need and be forced to repack. Furthermore, there is no workspace for the crew to work on and often use their laps or the patient to put their medication or equipment.
To ensure transferability of learning points across different helicopters and hospitals, the researcher interviewed a flight nurse from another level 1 trauma center and the head of the flight crew who oversaw the design of the interior for the two new EC145 helicopters.

**Extra space can be a problem**

There were numerous benefits of having a larger helicopter that include more space and taking heavier loads but it comes with the downside of higher costs of maintenance. The larger interior also caused the crew to now have problems reaching for things and having to stretch or move their seats to access things that used to be within arm’s reach.

**Distinct hospital needs**

The head flight crew stated the need for the larger helicopter was due to his hospital’s specialization in pediatrics, which required the extra space and equipment. He felt that most hospitals only need the EC135 as they use standard equipment.
Design method 7: WORK INVENTORY
adapted from Personal Inventory

This allowed the researcher to see and understand the relevance of the equipment. Ranking the level of usage of the equipment clearly showed that 50% was redundant as they had never been used but were in the helicopter due to regulations. Hence, the great irony of the Air Ambulance being required to carry a first-aid kit.

Learning points: Equipment placement

It also surfaced that the reason for the placement of equipment at specific locations was arbitrary. It was largely due to the ability to fit the equipment in the pouch rather than fitting the context of the procedures or treatments.

Unclear contents

The learnability for the contents of the pouches was challenging as there were no descriptions of the contents on the pouches. Furthermore, there were a total of 10 grey pouches that made it even more complicated to learn.
Design method 8: CARD SORTING

Learning that there were unclear organizing principles and redundancies in equipment, the researcher asked the crew to sort the equipment into groups based on usage patterns.

This resulted in a new organizing principle that was a combination of injuries/illnesses with usage level patterns that would allow for clearer hierarchies in the grouping and placement of medical equipment.

High need
Items that are needed to stabilize the patient or sustain life, especially for the common types of patients they transfer. (E.g. Cardiac medication)

High speed
Items that need to be accessed within 15 seconds. (E.g. Airway equipment)

High use
Items that are commonly used across different procedures and treatments. (E.g. Syringes, gloves)
The Air Ambulance is used to transport different types of patients based on the specialties of the hospital. Hence, there is no single type of patient that would be transported across hospitals. Furthermore, there are numerous requirements in the Air Ambulance that are sometimes competing or even conflicting.

These design dualities aim to be scalable across hospitals and helicopter models and serve as guiding principles to balance the conflicting requirements to enable the crew to safely transport patients and manage emergency situations when they arise.

**DISTINCT RESPONSIBILITY, SHARED ACCESSIBILITY**

The primary and secondary providers have distinct responsibilities but the disorganized space and poor configuration result in the inaccessibility to equipment, medication, or patient. Each is unable to carry out his own responsibilities efficiently and find it difficult to collaborate.

The redesigned space needs to ensure each personnel’s distinct role and corresponding responsibilities can be individually fulfilled but yet simultaneously allow for collaborative life-saving as a team when necessary.

**DISPLAYED INVENTORY, CONCEALED STORAGE**

The required medical equipment and medication are stored in a chaotic manner. Some are piled on top of each other while others are clustered together. Colors were inconsistently used, making it difficult to quickly know what equipment was in each of the pouches and drawers.

The range of inventory in the aircraft ought to be clearly displayed for ease of access and understanding. However, it should feel almost concealed until needed to reduce its overwhelming presence in the aircraft and elicit a spacious feel to the space.
PROVIDER-CENTERED, PATIENT-FOCUSED

The Air Ambulance uses similar principles as a hospital’s emergency room with the patient centered amidst all the equipment. In the aircraft, where space is limited, this results in the equipment forming a barrier that obstructs the medical flight crew and prevents access to the patient.

As the provider is responsible for stabilizing the patient, the equipment should be centered around the provider so that they may easily monitor and access the equipment and patient. This is to support the goal of keeping the focus on the patient.

DIMINISHED SENSES, ENHANCED SENSES

The equipment in the Air Ambulance have largely been transferred from the hospital’s Emergency Room (ER). The aural alarms that shrill in the ER can hardly be heard in the helicopter due to the engine, propellors, and helmets. Furthermore, there were numerous false alarms during the flight and the providers became desensitized to them over time. The redesigned interior needs to take into account that the senses of hearing and touch are greatly diminished due to the noise and vibration caused by the aircraft and to let sight and visuals take the forefront.
FINDING USABLE SPACE

With limited space in the aircraft, it was critical that the storage space not impede the access of the crew and yet allow for equipment to always be within an arm's reach.

Unofficial storage space

At present, the crew had found ways to store personal items that was not part of the medical inventory such as thick winter jackets. The space between the pilot seat and the secondary providers seat was currently used for unofficial storage. Thus, it was a good potential spot for a storage unit.

Wasted space

The researcher also looked for spaces that were overlooked and not used. The bottom of the seat was a great storage space as it could follow the provider and always be within an arm's length. Although there were reservations about using that space due to crash landing requirements for flexing, the researcher felt it was possible to allow storage and flex to co-exist for the seat storage.
Design method 9: SPACE PROTOTYPING

A low fidelity scaled mock-up was created in the home of the researcher for the development and testing of ideas.

In the space

Major components were marked in the space that include the stretcher and the thickness of the walls. The researcher did ideation sessions within the space to appreciate the sense of scale and used tape to figure out dimensions for scale.

Within arm’s reach

Reach was a crucial factor in the design of the interior. Sizing and accessibility were tested in the scaled mock-up to ensure the main components of the design was always within easy reach of the medical crew.
Design method 10: USER TESTING

The crew was actively sought throughout the design process to ideate on key aspects and to give feedback on the development of the concepts.

Sketching phase

The early stage had the team giving feedback on the sketches, having conversations over preferred ideas over others, and collaborating on thinking through the details on how to make the ideas work for their needs. The researcher also managed to convince the crew that an incremental improvement would do little to improve the space and a more holistic redesign was needed to address their numerous but connected frustrations.

Prototyping phase

As the concepts were further developed, prototypes were used to test for sizing and accessibility. This was done concurrently with renderings to help the medical crew visualize the final outcome.
INSPIRATION

Calm
Simple
Geometric
Subtle
PATIENT TRANSPORT MODE

- Primary provider’s seat
- Equipment storage unit
- Secondary provider’s seat
- Treatment packs storage
PATIENT TREATMENT MODE
Distinct Responsibility, Shared Accessibility

Primary Provider

The primary provider directs the care of the patient, communicates to the hospitals through the radio system and is responsible for intubation if breathing issues occur. He has clear access to the patient, to the equipment storage unit, and to the electrical controls within arm’s reach.

Secondary Provider

The secondary provider administers the care of the patient, monitors the patient through the diagnostic equipment, and performs emergency procedures when necessary. He has direct access to the patient, to the portable equipment carrier and to the treatment packs storage within arm’s reach.

Shared spaces

There are overlaps in the space and responsibilities to leverage on the close relationships the providers and even the pilot have. The overlaps allow the providers to blend their roles and responsibilities and to have the ability to pass things to each other.
Displayed inventory, Concealed Storage

Equipment storage unit

The equipment storage unit contains the high speed items on the left column to allow the primary provider to have full access at all times. It is also color-coded according to illness or injury-type so as to increase precision in getting what they need.

Treatment packs storage

The treatment packs storage contains the treatment packs that are segmented by different illness or injury-type. It serves as a work table for temporary placement of small medical items. It can be locked upright when not in use.

Treatment pack

The treatment packs contain the high need items for the type of illness or injury-type the hospital specializes in. It also allows the opened sterile packaging to be placed within the treatment pack.

Seat storage

The high usage items are in the seat storage as it can follow the providers if they move around. It is always within arm’s reach.
Collaborative life-saving

The providers have the new option to sit side-by-side with full access to all equipment with an almost entire full-body access of their patient as the stretcher can be pushed deeper into the helicopter. This allows for both primary and secondary providers to simultaneously treat the patient.

Collaborative monitoring

Both providers are now able to fully face the patient and place all their focus on the patient. If an emergency protocol needs to be performed, it allows the providers to use both their hands to administer to the patient. This mode is useful if the primary provider might need to intubate the patient. This configuration is most commonly used.

Collaborative piloting

The co-pilot seat is removed to increase the usable space and reduce the load on the helicopter. The primary provider is still able to move to the front and act as a navigator when travelling to the hospital. Thus, satisfying the current protocol.
Provider-Centered, Patient-Focused

Consolidation of equipment

All the portable medical equipment and medication are placed on the portable equipment carrier instead of on the patient so that it can be easily moved around with the stretcher. It is mounted to the side of the stretcher that will be against the wall so that the secondary provider is able to have clear access to the patient.

Single line of sight

The carrier consolidates the monitoring of the equipment. This enables the secondary provider to monitor the medication, equipment, and patient within a single line of sight. If any adjustments need to be made, it can also be done within an arm’s reach. Hence, enabling the providers to always remain belted.
Diminished Senses, Enhanced Senses

**Visual Attention**

Each of the treatment packs use consistent color coding to denote the disease or injury-type equipment that are contained within, allowing for precise location and retrieval of equipment.

**Visual Calmness**

The color palette for the interior uses more muted colors to create a calming effect to combat the vibrations and noise of the helicopter. This is contrasted with the strong colors used for the location of equipment when the storage needs to opened for emergency situations.
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