Handheld Mission Displays for Military and SAR Helicopters

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In a world where computers have become pocket-sized and integrated into almost everything, the question arises as to when, not so much if, this technology will reach the Military and Search and Rescue (SAR) helicopter market. This paper seeks to give the reader insight into the complexities behind the issue as investigated by the Tactical Processing department at Leonardo Helicopters. This work was sparked by a customer interest in avoiding weight and cabin configuration limitations of the pre-existing mission display solutions within the cabin of the aircraft such as mission consoles. Primarily among the discussion come issues of need, market availability and compliance with aircraft standards. Focused on addressing the problems of mission management with such a device, the investigation limits itself to devices which are compatible with a particular aircraft mission computer before touching on the possibility of what further integration may be possible in the future. The paper concludes that this investigation has given rise to a good understanding of the market, trade-offs, and impact on aircraft and mission systems for a handheld device within Leonardo Helicopters.

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List of Acronyms

CCD	Cursor Control Device
EFB	Electronic Flight Bag
EMC	Electromagnetic Conformance
FLIR	Forward Looking Infrared
GRD	General Requirements Document
HD	High Definition
HMI	Human Machine Interface
LCD	Liquid Crystal Display
NRC	Non Recurring Costs
NVG	Night Vision Goggles
RAM	Random Access Memory
SAR	Search and Rescue
TP	Tactical Processing
GRD	General Requirements Document

Introduction

The problems surrounding handheld displays on aircraft are more complicated than a user may initially assume. When operating in military and SAR environments, and where these displays are to some level integrated into the aircraft, complexity mounts considerably. In a world where everything is becoming more integrated and handheld devices perform more and more tasks it is perhaps natural that the question of integrated handheld displays should arise. Indeed within the Leonardo Helicopter Division in Yeovil alone there have been 2 or 3 projects related to handheld displays ranging from reducing maintenance burdens through to flight data and mission monitoring. The investigation followed by this paper focuses on mission displays. Mission displays, in this case, are integrated into the mission systems of the aircraft only, and have little to no influence upon the aircraft's flight systems. Data accessed is only that which is provided by the mission computer. The project to investigate mission displays followed customer interest taken on by the Company's Tactical Processing department. During this paper the rational, and advantages of handheld mission displays will be discussed. Once a grounding in 'why' is established this paper will highlight some of the difficulties in getting to a solution. These difficulties include a look at the options available in the current market, the aircraft standards needed to be met by those solutions, and why there is no ideal solution. To clarify the most important trade-offs a final high level comparison of available device options will be made before the opinion of the writer is followed into which option should be taken. Finally the next stage in the future of handheld mission displays will be shown, highlighting some of the potential this technology holds, before conclusions will be drawn on the results of the investigation conducted.

Problem Background

During 2016 a customer expressed interest in handheld mission displays and the Tactical Processing department at Leonardo Helicopters was tasked to investigate. The request would form part of an aircraft bid to this customer and was for a mission display in the cabin of the proposed aircraft, in addition to existing cockpit displays. Standard cabin installations for mission displays were dismissed by the customer as taking up too much space. The physical structure of the mission console which features in many SAR and military customers was seen as too limiting. A display that did not impinge on any of the cabin configurations was required. This meant that even rack mounted monitors that swung away into a storage position took up too much room. Traditional solutions were unsuitable and so handheld displays that could be stowed in a pocket or webbing became the obvious way forward.

Benefits of Handheld Mission Displays

Customers can use the cabin of an aircraft to fulfil a large number of roles making the helicopter very versatile. The customer has access to 'role fit' equipment that can be added and removed from the aircraft as required in a number of pre-determined configurations in the cabin. These include troop transport, various disaster relief roles, gunnery positions, and medical transport among numerous others. As highlighted by the customer, a significant factor in limiting these configurations is the space taken up by role fit mission displays incorporated within mission consoles. These mission consoles are essentially large computer installations that work in conjunction with the Mission computer giving the operator in the cabin access to mission systems such as radar. A handheld display could potentially be used to replace the mission console. This would open up large amounts of space in the cabin in a similar way to replacing a desktop PC with a tablet. The tablet will fulfil most tasks required, not take up the same footprint and allow the user to move more freely. Such a device opens up the versatility of cabin configurations greatly by allowing access to mission systems by the crew in any configuration.


Figure 1: Multi-role cabin, troop configuration (left: AW101, right: AW159)

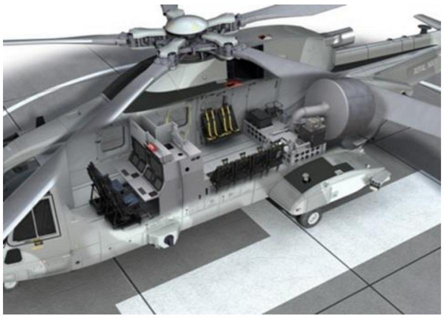
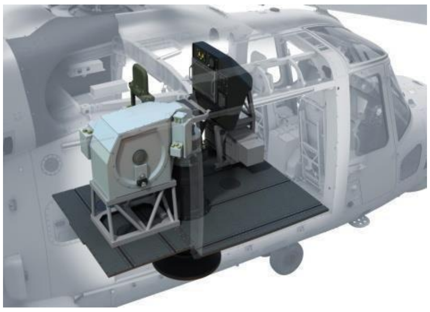

Figure 2: Multi-role cabin, configuration with mission consoles (left: AW101, right: AW159)

To demonstrate this idea Figure 1 shows example troop transport configurations without mission consoles, while Figure 2 shows a separated configuration with the mission consoles fitted. The mission console takes a large footprint that could be otherwise used for personnel and equipment. Space is not the only saving to be had; a mission console can weigh up to 100kg. A handheld display by contrast can weigh as little as 1.2kg. Even if there where multiple handheld displays there is still an impressive weight saving that could be used to increase flight time, carry more equipment or more personnel. While these in themselves would be benefit enough to warrant further investigation some additional benefits are apparent. In the AW159 and some AW101s the aircrew in the cockpit operate with one crewmember controlling the aircraft and one managing the mission system. Even with a crewmember solely devoted to mission system management there is a lot of data to process and the volume of mission data available to the crew will continue to increase as technology advances. Using the mission consoles, additional crew in the cabin of the aircraft are able to assist in management of the mission and so alleviate some of the load on the crew in the cockpit. With handheld displays this benefit could be extended to AW159 crews, and more AW101s with little loss of capability if replacing a mission console. The scenario could be envisaged where the whole crew could potentially be involved in mission management. An additional benefit to the crew and passengers would be increased situational awareness. The winchman operating in low visibility could have his vision improved greatly by giving him access to the on board electro-optic cameras. Troops deployed into a hostile environment could benefit from being able to pass round a live tactical map showing exactly where the threats are in relation to the drop zone just before landing.

Work to Date

In order to understand the displays and suppliers available to provide hand held solutions a detailed market investigation was carried out. Of those investigated 7 suppliers were contacted about their candidate products before being invited on site to discuss their products in more detail. Each candidate product investigated was compared with the proposed integration solutions, the General Requirements Document (GRD), and assessed in terms of the Human Machine Interface (HMI). One key constraint affecting the integration with the mission system was the need to limit the impact on the existing mission computer, the Leonardo Helicopters Tactical Processor, both in terms of hardware and software changes. There is also significant software development cost to redesigning pages for a different type of user interface and so to choose displays that make it possible to re-use pre-existing pages was important. Finally supplier input into possible solutions played an unexpectedly pivotal role in writing design requirements making it imperative to understand the available options before some requirements could be fully designed.

Proposed Solution

Due to the constraints of the mission system hardware and for ease of integration the architecture illustrated in Figure 3: Proposed mission display integration solutionFigure 3 was proposed. Integrated Display Units (IDUs) are cockpit displays which show the flight data and instruments required by the pilots to fly the aircraft. They also have the capability to seamlessly display the mission computer data pages such as radar by switching to a video feed from the Mission Computer and sending button press information back to the Mission Computer. All the processing that pertains to the mission displays happens within the mission computer. This is a similar arrangement to a desktop computer displaying video to a monitor and reacting to button press information from the keyboard and mouse. The handheld display would only show mission views and will work in the same way as the IDUs do for mission displays, taking a video feed in and responding with button press information. While a number of interface solutions were investigated it quickly became clear that touchscreen would be the primary means by which a user would interact with the display. To have buttons in addition, similar to the IDUs, would be preferable and a minimum of 3 were specified where possible.

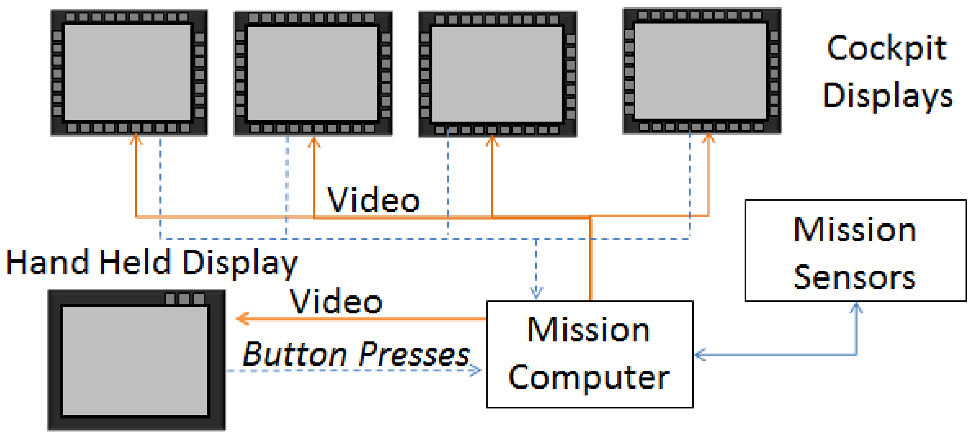

Figure 3: Proposed mission display integration solution

The Current Market

Military display suppliers had a number of standard designs but could also customise designs heavily to suit their customer's needs. For the most part these suppliers build panel mounted displays for land vehicles and maritime craft; however, there are some examples of aircraft use such a Curtis Wright display we found to be in use on some police helicopters. Military display suppliers' displays tend to be heavy and relatively costly but are well suited to the harsh environments they are designed for. In contrast there were the rugged tablet suppliers mass produced Commercial Off-the-Shelf (COTS) only devices which were significantly cheaper than the military display suppliers. The tablets were of much lower build standard and environmental qualification, but as well as being cheaper were also much lighter. Rugged tablets are primarily used in industrial applications but more and more in the aerospace industry as Electronic Flight Bags (EFBs). Looking into more detail it will become apparent that both options have significant advantages and disadvantages leading to a difficult trade off.

Figure 5: Inzpire Tablet as EFB on pilot's leg © Inzpire.com

Figure 4: Inzpire tablet EFB moving map © Inzpire.com

Aircraft Standards

Environment

Leonardo Helicopter's aircraft operate in extreme environments and on-board equipment is expected to be qualified to withstand such environments. The aircraft are designed to operate anywhere from hot deserts of the Middle East to the extreme cold of the Arctic Circle, see Figure 6. Equipment should operate within a temperature range of -40°C to +70°C and be able to survive storage at temperatures as low as -55°C and as high as +90°C [1]. A standard Liquid Crystal Display (LCD) screen will only withstand temperatures of 0°C to +50°C [2] with the cells either freezing or boiling outside of those bounds. LCD displays that can operate from -40°C to 80°C are available but not in the sizes required. Suppliers were able to offer fans, venting and air conditioning solutions to meet requirements, however, these solutions incur additional bulk and weight. With moving parts like fans the problems of dust, water and sand intrusion presents itself. Aircraft equipment must give protection against corrosion and erosion caused by the intrusion of dust, sand and water subject to the requirements of DEF STAN 00-35 part 3 referenced in Leonardo Helicopter's GRD [1].

Figure 6: AW159 tested in Norway © adsadvance.co.uk

While equipment in the cockpit may expect some level of protection from the aircraft itself the handheld display could not expect such luxury. Placed in the cabin where the large cargo doors on the aircraft may well be open they could be fully exposed to the elements. Surprisingly it was the tablet suppliers that were often better able to demonstrate some level compliance to dust, water and sand requirements. Most military suppliers designed for cabins in ships and tanks, well protected spaces, so did not qualify the displays as a normal procedure. By contrast rugged tablets used in industrial applications were expected to be out in all weathers and conditions that people normally work in hence tablets were regularly qualified to ISO6/7, a civil standard for environmental sealing. Aircraft working at night and particularly those in the military environment need to be able to use Night Vision Goggles (NVG), a requirement in Leonardo Helicopter's GRD [1]. While this was not a problem for any military display supplier, the tablet suppliers were more constrained. As off-the-shelf equipment is used across the world, the suppliers would not alter their design to suit our precise requirements. For example to suit NVG goggles for the relatively small amount of displays Leonardo Helicopters would purchase. The only recourse therefore was to use a filter bonded across the screen. Unfortunately the filter degraded a tablet's ability to display a clear picture for bright sunlight as well as reducing the overall picture clarity.

A further particular issue to helicopters is vibration which carries a particularly stringent set of requirements. Aircraft equipment must be able to withstand the vibration propagating from the main rotor head which is mainly 5R, a primary driving frequency for a 5 bladed aircraft [3]. While many displays will withstand a short exposure to such vibration, a display provided by this mission display would need to withstand long term and continuous exposure. As role fit equipment it would be expected to be on the aircraft for significant periods. A handheld display could expect a degree of protection from the rigors of vibration while held by a user as the body will naturally cushion the display, however, this display will at some points be mounted or stowed on the aircraft body and so subject to vibration. None of the suppliers contacted were immediately able to give compliance to Leonardo Helicopter's standards and requirements but it would be expected that a military supplier, more used to such requirements and rigor, would be more easily be able to provide compliance. Perhaps the most trying and telling test for a handheld device is its users. A user could be fully expected to drop, kick, stand on, and generally abuse the display however unintentional those actions may be. The build quality of military displays seemed to share our pessimism regarding how careful the owner would be. Often with metal chassis and bodies, vibration mounts and heavy duty connectors these displays could be expected to survive a great deal of abuse. The tablet displays, were classed as rugged and often came with statements such as "drop resistant" [4]. Their construction was a great deal flimsier, plastic bodies and rubberised corners, seemed much more likely to break due to physical impact.

All these factors and many other environmental requirements for aircraft equipment culminated in a penalty for the user, display weight. A military display supplier could meet all or most of Leonardo Helicopter's requirements however this compliance came with a great deal of weight. One supplier even went as far as to describe a 9kg display as "Ultra-Light" in their publicity. Not exactly light enough to be handheld. In fact the lightest a military display supplier would promise was 3kg. The commercial tablets compromise on many requirements, just missing some and not coming close to others, but they are much cheaper and much lighter. For example a 10.1" Panasonic Toughpad comes in at just 1.1kg [5]. This compromise means the investigation was left with a trade-off to make, light, cheap and breakable, vs expensive, heavy and robust.

Human Machine Interfaces (HMI)

After considering environmental standards it was important to think about the standards needed to make the mission computer display pages useable with a handheld display. This area involved a large amount of subject assessment of device ergonomics, consultation with Leonardo Helicopter HMI specialists, investigation of previous studies, and assessment of mission computer pages demonstrated on a tablet. As previously mentioned, touchscreen was selected as a primary user interface. The mission computer pages were not designed for, nor had ever been used with a touchscreen, opting for Cursor Control Devices (CCDs), similar to a tracker-ball mouse, physical keyboard units, and bezel keys round the display sides. An emulated software version of the mission computer pages was used on a Windows 7 tablet to prove the concept and see what work needed done. This emulation ran most mission computer pages to some degree and allowed the testing of all menu systems with the touchscreen on the tablet acting in place of the CCD. Surprisingly, for an interface not designed with touchscreen in mind, the menus and buttons on the mission display would require very little alteration to work with touchscreen. Unfortunately there were still a number of considerations to tackle. It was found in subjective assessment using standard issue flight crew gloves that accuracy and ability to use the display was diminished but still possible. Large bezels on the edges on some displays made it impossible to reach some buttons; a feature more prevalent on military displays than tablets. Generally flight crew gloves are made of thin leather and so even the capacitive touch screens of the rugged tablets were able sense a user's finger. However the fingertip seams made it harder to sense the accurate position of a user's fingertip even when displays had "glove mode" enabled, increasing the tablet's ability to sense a user's fingers through gloves. The military monitors had the choice of using resistive touchscreens. These screens were not as sensitive as their capacitive counterparts without gloves but lost none of their sensitivity to gloves and could be used with any thickness of gloves. With both military displays and rugged tablets gloves highlighted a need to have a minimum button size and also consequently a minimum display size. Vibration was another factor that affected this issue. Although it was assumed that vibration was dampened by a user's body while the device was in use it would still have some effect on accuracy and speed of touchscreen use. Although a thorough investigation to quantify this effect was unable to be conducted due to time constraints a previous investigation into touchscreen use was available. The report gives the guideline minimum keyboard button sizes of 14x16mm and 15x18mm for graphic buttons not in a keyboard [6]. This assessment was on a user operating a unit at arm's length that was fixed to the aircraft body and so subject to much greater vibration and touch accuracy than a handheld display, however it did provide a baseline to make a judgement from. The conclusion drawn from all the work on touchscreen compatibility was that the minimum display size of 10.4" in the diagonal with an aspect ratio of 4:3 should be implemented. The aspect ratio was dictated by the output format of the pages from the mission computer. 12.1" was settled on as a guideline maximum size in the same aspect ratio. It was considered that a larger display would increase weight unsustainably for a handheld display; additionally this is the size of the cockpit displays and it was thought that larger was unnecessary as the users would be holding the display considerably closer than the cockpit displays. Considering tablet displays within the bounds of these requirements highlighted a problem with tablets. All rugged tablets come in widescreen 16:9 aspect ratio. This means that in order to match the requirement for a 10.4" display in 4:3 aspect ratio we would be required to get a larger 16:9 display to ensure the 10.4" display area fitted within the screen without scaling down. A possible benefit to this method could be found in the unused screen space left over from the mission computer display area on the tablet screen. If that area was used for some buttons and functions normally overlaid on the mission pages or on bezel keys round the side of the display the mission display picture could be decluttered. This idea would come with a cost in software development and hours, so again a compromise needs to be sought. An example concept design can be found in Figure 7.

Figure 7: Example HMI design on a tablet

Integration & Security

The mission computer considered in this investigation outputs a proprietary uncompressed video format to send video data over optical Ethernet to the cockpit displays. Unfortunately Optical Ethernet was only supported by a limited number of military display suppliers and at an extra cost. Instead other options such as Analogue Video or Copper Ethernet were considered as integration was assessed. Figure 8 demonstrates some of the difficulties to overcome. Ethernet video was the only option available from the tablet suppliers. Due to the high data rate of the video format used, only tablets with Gigabit Ethernet cards could be considered. Other compressed video formats were not considered as this would require significant software changes to the mission computer. In order to return button press information to the mission computer via Ethernet an Ethernet switch would be required as the mission computer has separate input and output ports. Military Mission displays by their nature of being designed to meet Leonardo Helicopter's requirements could have Ethernet video or analogue video input and could support a separate return path for button press information negating the need for an Ethernet switch. With a display in the rear of the aircraft allowing a user to interact with the same mission pages as the users in the cockpit multiple user support needs considering. Some builds of the mission computer already support 1 or 2 extra users depending on customer requirements to support mission consoles. Where a handheld tablet was used as a direct replacement for a mission console the mission computer may not need upgrading however where there is no multiple user, support mission computer hardware and software upgrades will be needed.

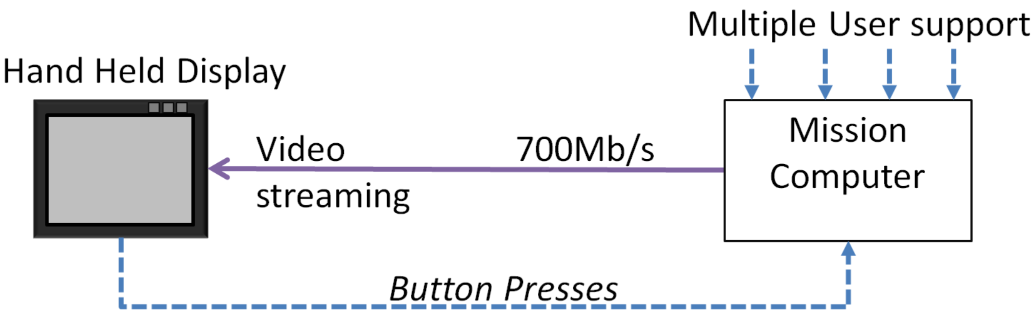

Figure 8: Mission display and handheld integration

Security was briefly considered. The main concern for a handheld device is it being removed from the aircraft while holding secure information. That concern is somewhat mitigated by the use of video streaming. This means that the display will only hold a few frames in Random Access Memory (RAM) at any time. Particularly with a tablet display further mitigation is available through encryption of the device.

Crash Case

The last area to consider was the crash case. While stowed, in webbing for example, the risk is mitigated due to the already crashworthy qualified webbing. In the case of the display being in a user's hands during a crash the display will inevitably come loose. Here the lighter display options of 1-2kg tablets hold a significant advantage over the 3-9kg military displays. Reduced weight and the softer composition of the body, plastics rather than metal, are less likely to cause serious injury. In a crash case the cables used to power and supply data to the devices could cause entanglement issues, possibly hampering crew and passengers exiting the vehicle. In the first instance this risk could be mitigated by the use of quick release cables. Unexpected turbulence may also cause the device to come loose from a user. If this was to occur a loss of the display overboard is conceivable if doors are open on the aircraft. If the device was to fall cleanly away the only concerns are it remaining intact to cause security concerns mentioned above and injury to people on the ground. However with a cable attached it is likely to dangle and swing potentially causing damage to the aircraft or injury to anyone on the winch. A thorough investigation was not possible here due to time and cost constraints however again it was thought that lighter would be better.

Trade-off between Device Types

Figure 9 shows a summary of the main points involved in the trade-off between the available market options of handheld tablets and custom military displays.

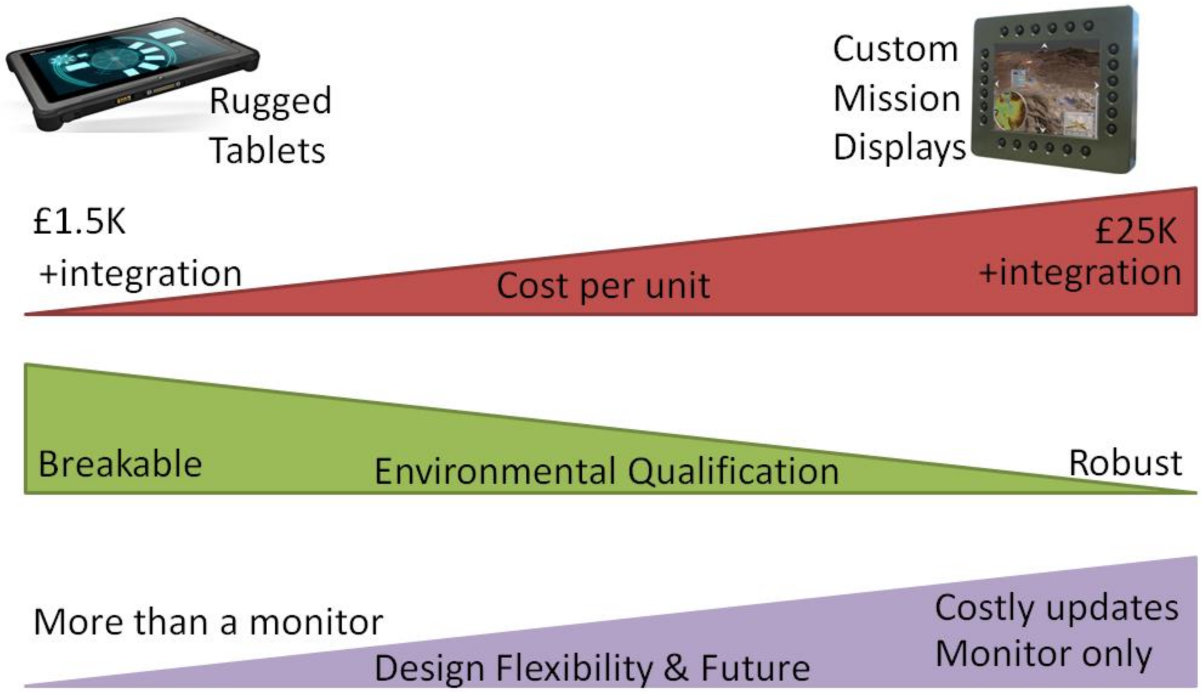

Figure 9: Device types trade off

The tablet display option commands a much lower per unit cost of roughly £1,500 per unit, while the military displays are much more expensive. This cost is somewhat balanced out by integration costs which fall in favour of the custom military displays. The tablet method requires a greater level of hardware and software integration to make it work as effectively as a customized military monitor. Environmental qualification comes down to the question of whether to provide the customer with a display that will suit and survive most environments at a high cost or receive a display that is breakable but so cheap it becomes disposable. An important point in that discussion to consider is loss overboard; a cheap display may be preferred if that is likely. Where the tablet comes into its own however is as the future of such technology is considered. A custom display designed to meet Leonardo Helicopter's requirements now may not meet them in 5 or 10 years' time without costly updates. Additionally it is a monitor only without additional functionality outside of the mission computer. Whilst a tablet comes with a higher up front integration cost allows for greater future development of handheld display technology without such great hardware cost. It can be more than a monitor, with the ability to install other programs and apps and has the potential to seamlessly transfer to wireless communication with the aircraft.

Future Updates

As Figure 10 demonstrates, the team also briefly considered how to best exploit a handheld device's advantages in future updates. Using Ethernet will allow plug and play with already available wireless routers. Wireless technology would remove wires from the cabin reducing entanglement issues, making the display easier to pass round the cabin. Troops viewing a tactical map, for example, would become all the easier. Wireless will also allow easier connection of multiple devices; multiple handheld devices being something one customer told us would make this technology very much more attractive. Portable devices are already being used to access tactical video and data links. A tablet device would allow for a customer to install the software to access the datalinks without need for a secondary device and screen or manage the datalink through the mission computer. The ability to install other software could also conceivably allow aircraft maintainer and mission planning programs to be added. Imagine the possibility of a crew who are able to plan their flight on a handheld device and walk out to the aircraft where the mission planning data is automatically synced to the aircraft as the tablet connects to it wirelessly. Once it is synced the tablet can continue to be used to manage the mission in parallel with the on board mission computer. Flight and maintenance data could also be synced and used to better manage aircraft flight readiness once the mission is over. All this opens up the possibility of turning Leonardo Helicopter's aircraft into a forward command centre among other possibilities. Finally as tactical video links are already HD video ready and Forward Looking Infrared (FLIR) turrets are starting to become HD. It would be preferable to move all displays and the mission computer to be HD capable to take best advantage of the better picture quality.

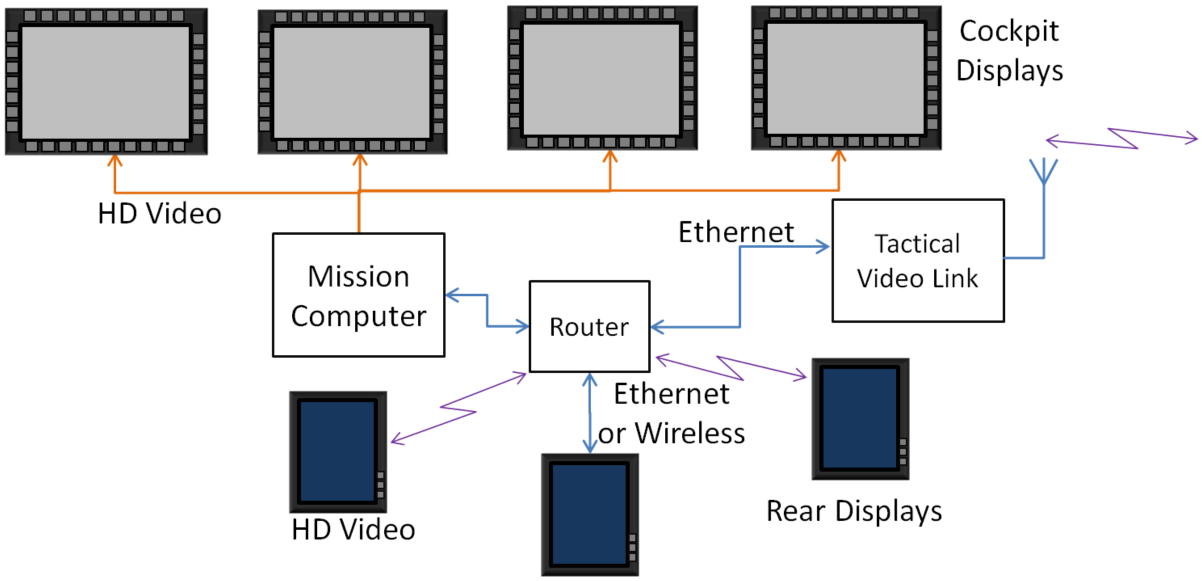

Figure 10: Future handheld display integration

Unfortunately there are a number of issues to overcome in handheld displays before even this near future concept is accessible. Portable heads up displays or holographic moving maps in the cabin will have to wait for some time yet. Firstly the more security conscious readers will already have raised eyebrows at the idea of wireless on aircraft. There are some valid concerns. Could a wireless router be used to track and even target an aircraft? A wireless router moving quickly across the sky might be a bit of a give-away to a stealthy approach. Furthermore the issue of hacking presents itself. Could someone either gain access to data or control of any systems through such a router? Finally there are known reliability issues with wireless routers at home let alone in the interference heavy environment of an aircraft. There are some precedents set however. One of Leonardo Helicopter's AW101 customers, for example, has a normal wireless router on board used for datalink access. If radio silence is required the router can be disabled and the data link connected to using Ethernet cables instead. Additionally, other technology is available over and above the normal WiFi router. LiFi (Light powered WiFi to the layman) works by flickering on an off LED lights and is possible to make compatible with Night Vision Goggles. While this technology is in its infancy it shows strong promise for the future with Gb speeds possible [7]. Local low powered wireless that only covers a few meters is possible [8] [9], or even avenues of exploration into wideband wireless only looks like white background noise unless you know it's there [10]. A further big step needed to get to the proposed future concept will be hardware and software upgrades for the mission computer to support multiple users and HD video. Finally the testing required to pass Electromagnetic Conformance (EMC) requirements and security with wireless will be a hurdle. Security will hopefully be answered to a greater degree with encryption.

Conclusions

During this paper the subject of handheld displays on military and SAR aircraft has been discussed. It has followed the conception of the idea through the requirements and justification for such a display. The availability of suitable displays was investigated. Following from that the trade-off between available device types from suppliers has been demonstrated in terms of environment, HMI and integration. Safety was briefly considered to show some consideration to all areas thought about as part of the investigation. A high level trade-off was then shown to highlight the most important issues before looking into the near future using ruggedized tablets as a preferred option from the writer's point of view. Having considered all of these issues it can be concluded that there is indeed a viable place for handheld mission display on military and SAR aircraft. Leonardo Helicopters has been able to develop a mature set of requirements demonstrating a good knowledge of the market, an understanding of mission system impact, qualify the aircraft design implications and create a customer proposal that is in use today.

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