Experiences and Lessons Learned Constructing Composable Adaptive TeamSpaces

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ABSTRACT

This report describes a Composable Adaptive TeamSpace (CAT) used to provide enhanced distributed collaboration support in mobile and/or re-deployable defence environments, and the lessons learned during the exploratory design and development phases. Various components of the CAT are discussed in detail, in particular the frame system, the whiteboard and pinboard wall panels, and the design and construction of the access panels, which act as hubs for data and power around the CAT. Experiences working with third party service providers (both internal and external) are also presented. To take advantage of the experience of this exercise, more than sixty recommendations are made for consideration during the design and construction of new CATs.

RELEASE LIMITATION

Approved for public release
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Executive Summary

Under task LRR 07/248 and later LRR 07/313 a Composable Adaptive Teamspace, or CAT, was prototyped to explore and investigate how the core Livespaces capability (Vernik et al., 2004) could be quickly integrated with custom off-the-shelf structural elements and ICT infrastructure for applications in mobile and/or re-deployable operating environments. This work represents a comprehensive exploratory design and development effort aimed at eliciting requirements and understanding the complexities and challenges involved in developing CATs for mobile and or re-deployable Defence Force environments. Many of the lessons learned in the R&D of the fixed room Livespaces instantiations, such as the Intense Collaboration Space at DSTO Edinburgh and the Battlelabs at the Deployable Joint Force Headquarters and the Australian Defence Force Warfare Centre, have been critical and instrumental in guiding the work.

By demonstrating the feasibility of the CAT concept, we are able to show that enhanced distributed collaboration support can be provided to mobile and/or re-deployable Defence Force environments without requiring significant and lengthy facilities work to be done. This report demonstrates how an existing space (e.g. a factory floor, a room on a ship, a warehouse, a tent, a shipping container, or the back of a truck) can be easily fitted out with custom off the shelf “Meccano” style structural elements and integrated with the core Livespaces technology together with other ICT infrastructure in relatively small time frames (less than a week depending on complexity and requirements).

In essence a CAT consists of a modular and configurable room-sized frame structure constructed of primarily COTS products and the Livespace ‘smart’ collaboration environment (hardware and software) that it houses. The instance this report describes consists of a custom designed frame, made of Octanorm components, with inner walls of whiteboards and pinboards, and frame-mounted collaboration devices (e.g. projectors, screens, cameras, microphones) which connect back to a dedicated co-located rack of computer equipment via modular and custom-designed access panels.

The purpose of this report is to detail the experiences of constructing the CAT so that if and when new ones are constructed the lessons learned are taken into account to avoid pitfalls and to streamline progress. A total of 66 recommendations are made on the basis of the lessons learned, which are collated at the end of the report for easy access. The recommendations cover the issues of:

- System design considerations
- Component design, manufacture, and combination
- Construction procedures and considerations (including with regard to security and IT infrastructure administration requirements)
- Interaction with vendors, contractors, and Scientific Engineering Services and the development of tenders, and
- Project management

Further development and improvement of this particular CAT is currently underway as a result of its inclusion in the C3I Integrator demonstrator 2.0 activity. This development is primarily in the form of fitting out the CAT with collaboration technology and equipment specific to the activity; however, the components within the CAT guide the development of integration of these technologies (e.g., mounting points and devices and revisions of the access panels, discussed in the report in detail).
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Derek’s primary recent work has concerned the Livespaces framework, an implementation of a tuple space and model-driven service architecture to support collaboration through meeting room device control and provision of a communications layer for groupware. Prior to that Derek worked on a component-based information visualisation framework called InVision, and before that on a distributed imagery and geospatial information exploitation system.
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## Acronyms, Terms and Abbreviations

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<th>Expansion</th>
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<tr>
<td>AuSPlanS</td>
<td>Augmented Synchronised Planning Spaces</td>
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<tr>
<td>BattleLab</td>
<td>Livespace applied to the domain of Command and Control</td>
</tr>
<tr>
<td>CAT</td>
<td>Composable Adaptive TeamSpace, the entirety of a Livespace housed within a modular frame system.</td>
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<td>CCSL</td>
<td>Composable Collaborative System Laboratory</td>
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<tr>
<td>COTS</td>
<td>Commercial off-the-shelf</td>
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<tr>
<td>CSCW</td>
<td>Computer Supported Cooperative Work</td>
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<tr>
<td>CSIRO</td>
<td>Commonwealth Scientific and Industrial Research Organisation</td>
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<tr>
<td>DSTC</td>
<td>Distributed Systems Technology Centre</td>
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<td>DSTO</td>
<td>Defence Science and Technology Organisation</td>
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<td>FOCAL</td>
<td>Future Operations Centre Analysis Laboratory</td>
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<td>ICS</td>
<td>Intense Collaboration Space, a Livespace installation at DSTO Edinburgh</td>
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<tr>
<td>IP</td>
<td>Internet Protocol</td>
</tr>
<tr>
<td>iROS</td>
<td>Interactive Room Operating System (Johanson et al., 2002)</td>
</tr>
<tr>
<td>KVM</td>
<td>Keyboard/video/mouse switch</td>
</tr>
<tr>
<td>Livespace</td>
<td>A technology-rich collaboration environment supported by the Livespaces Operating Environment (Phillips, 2008).</td>
</tr>
<tr>
<td>NICTA</td>
<td>Australia’s National Information and Communications Technology Centre of Excellence</td>
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<tr>
<td>PVC</td>
<td>Polyvinyl chloride, a type of plastic commonly used in construction, for example as a material for pipes and channels for wiring</td>
</tr>
<tr>
<td>SES</td>
<td>Scientific Engineering Services</td>
</tr>
<tr>
<td>UniSA</td>
<td>University of South Australia</td>
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1. Introduction

1.1 Purpose

This document describes the experiences and lessons learned while constructing a Composable Adaptive TeamSpace (CAT) in room 2.G.58 of Laboratory 205 at DSTO Edinburgh (Figure 1). The term LiveFrame has also been used to describe this structure, as in essence it is a modular, free-standing frame which, when coupled with COTS and customised components and integrated with the Livespaces core components (Phillips, 2008), provides a common framework (or infrastructure) for deploying and supporting a variety of domain specific Livespaces applications. As such it is designed for multiple assembly/disassembly cycles, and is suitable for supporting wiring for power and data and many common collaboration devices, such as projectors, projection screens, and whiteboards. The CAT’s purpose is to demonstrate the concept of a Livespace collaboration environment (Phillips, 2008, Vernik et al., 2004) which is able to be assembled and disassembled within a week. It is the third DSTO iteration using physical configurable frames as part of a Livespace installation. The findings of this report should be considered when developing new CATs to improve and streamline construction.

Figure 1  The Composable Adaptive TeamSpace in the Composable Collaborative System Laboratory at DSTO Edinburgh, while in use
1.2 General Requirements

The intention of this project was to develop a modular, configurable frame-based workspace that is easy to assemble and disassemble to provide housing for a Livespace collaboration environment. The frame would support heavy devices and associated wiring (up to 135 kg) and be able to be assembled by a small number of relatively untrained people in a short period of time. This was regarded as an exploratory proof-of-concept, rather than an exhaustive research effort designed to develop the optimal transportable collaboration environment, and resources spent on particular details of design were scoped accordingly.

Once work had begun, it eventuated that the only construction environment available was room 2.G.58 in 205 Labs at DSTO Edinburgh, the layout of which is shown in Figure 2. As a result the requirement that the frame be entirely constructable from the inside was introduced. This enabled us to take the greatest advantage of the space available while removing the luxury of access from outside the frame during construction, making some tasks more difficult (e.g. laying cables and attaching wall cladding like whiteboards and pinboards). This further constraint allowed us to consider and develop techniques for construction that do not rely on external access, increasing the amount of usable space in any given environment.

![Figure 2](image-url)  

**Figure 2** The floor plan of 2.G.58 in 205 Labs at DSTO Edinburgh. The ceiling height is 2.5 m; however, there is considerable bowing in the floor and walls, up to 50 mm across the long walls, for example, so CAT designs needed to account for this.

The resulting room has been labelled the Composable Collaboration Systems Laboratory, or CCSL.

1.3 Scope

Covered in this document are the characteristics and experiences with the non-computing hardware components of the CAT and the project management experiences in developing the CAT. Ultimately the CAT will house or be fitted out with workstations, computing, and
audio/visual hardware and custom-developed software, but development so far has been limited to the construction and fit out of the frame, wall cladding, motorised projection screens, lights and wiring.

In detail this report covers:

- the experiences of managing the project of constructing the CAT,
- the modular Octanorm frame system, its design and construction,
- the whiteboards and pinboards which act as walls inside the workspace created by the frame,
- the lights (both fluorescent and down-lights),
- the access panel and distribution board systems that provide data and power to various parts of the workspace, and
- a variety of mounting brackets.

In particular it is necessary to make explicit what is not covered by the report. Development to date is limited to only the physical environment, and although numerous Livespace installations including software and computing hardware have been developed, the CCSL has not been fitted out with such equipment at the time of writing (although fitting out is in process). It is expected that the selection of this equipment may require significant research that is better addressed in an independent report. In particular, this report will not be addressing the choice or performance of computers, both servers and workstations, tablet screens, KVMs (keyboard-video-mouse terminals that are shared between multiple computers), audio and video hardware, whiteboard capture devices, projectors, and any software, as these considerations are dependent upon the application of the overall system and its required functionality.
2. Background

The Livespaces concept was first described by Vernik et al. (2004) stating that a Livespace is a smart, highly adaptable and configurable, dynamic collaboration environment. Born out of the Computer Supported Cooperative Work (CSCW) Intelligent Interactive Workspaces research area, it aims to enhance collaboration between individuals, specifically synchronous intense collaboration, with the support of technology able to be used in a way that does not distract the users from their purpose. For this reason the technologies developed and used, both software and hardware, need to be unobtrusive and easy to use, helping the users rather than hindering them. To achieve this, great efforts have been made to make use of common and programmable off-the-shelf collaboration technology integrated via DSTO-developed software thus providing support to coordinate the operation of various devices and information services easily and simultaneously via customised user interfaces. To be responsive to changing requirements, a Livespace must be highly configurable and adaptable, and smart (to a degree) to determine how it should adapt to the collaboration session currently being carried out within it. The work has culminated with the creation of the Livespaces Operating Environment software system, which underpins all installations (Phillips, 2008). Although Livespaces have typically been constructed within buildings as fixed installations, there has always been the intention to develop a deployable or transportable Livespace, housed within a configurable frame, so that it might be used in the field as a short-term command centre.

The first application of the Livespaces concept was to provide support for military joint planning as part of the Augmented Synchronised Planning Spaces (AuSPlanS) project (Evdokiou et al., 2004) in conjunction with the University of South Australia (UniSA) and the Distributed Systems Technology Centre (DSTC). Other Defence domains, such as training and simulation, have since been identified and progress has been made to develop BattleLabs in operational environments for these purposes. Since AuSPlanS, other related collaborations have formed and the Livespaces concept is being applied to different, non-Defence domains. It was being used as part of the HxI Initiative, an arrangement involving the National Information and Communications Technology Australia (NICTA) and the Commonwealth Science and Industry Research Organisation (CSIRO). That initiative aimed to support a broad range of domains, but initially targeted health and e-research as well as national security (Schremmer et al., 2006).

The first Livespace installation was the e-World Laboratory at UniSA (Blackburn et al., 2002), which consisted of one main projected screen (projected onto a SmartBoard\(^1\)) and two smaller secondary projected screens on one side of the primary screen (see Figure 3). Also in the room was a large meeting table with a wireless keyboard and mouse that could be passed from participant to participant for control of the screens. Although individual computers drove each of the projected displays, they could all be controlled by one keyboard and mouse via the PointRight application (Johanson et al., 2002), which was part of the Interactive Room Operating System (iROS) from Stanford University (Johanson et al., 2002). Automation of various devices and services in the room (including Microsoft PowerPoint and other media

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\(^{1}\) [http://www2.smarttech.com/st/en-US/Products/SMART+Boards/default.htm](http://www2.smarttech.com/st/en-US/Products/SMART+Boards/default.htm)
services for automated presentations) was provided by the ODSI software contributed by DSTC (Bond, 2001).

Figure 3  The e-World Laboratory Livespace at the University of South Australia, Mawson Lakes Campus (circa 2004), Figure 1 from Evdokiou, Thomas & Vernik (2004)

The second Livespace installation, the Intense Collaboration Space or ICS, was developed at the DSTO site at Edinburgh in South Australia. Initially the software integrating the devices was duplicated from the e-World laboratory, but it has since been replaced by a more fully integrated DSTO-developed Livespaces Operating Environment (Phillips, 2008). Learning from the experiences of the e-World laboratory, the ICS has far more equipment and at the time it presented the first opportunity to experiment with frame materials. Figure 4 shows a 3D model of the contents of the ICS in mid 2005, which included:

- projectors on a configurable railing system (not shown in Figure 4 due to the figure’s perspective),
- whiteboards on rails over walls of pinboard material,
- a touch-screen next to the entrance providing a single interface to control the devices in the room (not shown in Figure 4 due to the figure’s perspective),
- a modular desk system covered in whiteboard material with data and power access features,
- microphones and cameras for audio/video capture and video teleconferencing,
- tablet workstations for each participant and dedicated display servers and
- other servers for specific purposes such as speech transcription.

Figure 4  A 3D model of the Intense Collaboration Space and its contents, circa 2005

Figure 5  A diagram of the projector railing system in the ICS, as seen from underneath. Each projector can slide sideways along its beam, and the whole beam can slide forwards and backwards. Also, projectors can be attached to the other beams.
Of particular interest, however, is the ceiling-mounted projector railing system (see Figure 5), which allows users to vary the location and orientation of the projectors. It consists of several orthogonal pieces of Unistrut C-channel and projector mounting brackets that allow them to be slid along a piece of channel. Since the creation of the ICS, there has not been a need to rearrange the projectors, so the ease of manipulation of the rails and brackets has not been tested. New projector mounts, similar to the ones in FOCAL, described later, have been installed to help prevent projectors losing alignment, as the original ones were prone to shift due to vibrations in the room caused by people walking around.

The third Livespace in Adelaide (and the second at DSTO) is located in the FOCAL. Unlike the previous two Livespaces, its construction was arranged chiefly for a Pozieres Development Exercise with time and budget constraints. Within those constraints its intention was to experiment with the idea of a re-deployable Livespace and, as such, it consists of an entire frame creating a workspace within the FOCAL itself. Devices such as whiteboards, projectors and cameras attach to the frame, which is made of Unistrut C-channel. The frame is bolted together and is therefore not as easy as a ‘snap-lock’ style system to assemble and disassemble, and although the C-channel used is convenient for running cables along, it is not sufficiently strong or sturdy to be used in the field (though it was not designed for this purpose, and this has not been tested). Revisiting the design with more time and resources could significantly enhance its suitability as the frame component of a CAT.

Other frame systems have been developed at Head Quarters 1st Division (HQ1Div) in Enoggera Barracks in Queensland by Dr Ken Skinner and Dr Glenn Moy, primarily as practical systems for supporting operational military staff during exercises and training and not as vehicles for DSTO research. These systems were based upon the ICS’s Unistrut ceiling system and the FOCAL frame design and then modified according to local needs, however, other than being firmly attached to surrounding walls and not being free-standing, they are not significantly different from the FOCAL frame.

The frame requirements for the CAT were strongly guided by the experiences with the FOCAL, ICS, and HQ1-Div frames. Although the specific requirements are listed in the Statement of Requirements (Section 4), the overarching aims of the project included modularity, flexibility and ease of construction. The original guidance (prior to the availability and consideration of the CCSL as a construction space) was to develop a frame that could be housed within a standard army tent with a view to providing a Livespace capability in the field. The prototype developed allows for this type of deployment; however a great deal more research and development is required for ruggedising the various components to specific operational, transportation, and storage environments, and targeting the functionality of the product to end user requirements. The prototype developed provides a broad range of functionality to ensure flexibility of application, and, as such, should be regarded as a concept demonstrator rather than a finished product ready for use.
3. Previous Experiments with Frames

3.1 Intense Collaboration Space

The frame installed in the ICS is limited to supporting configurable, repositionable projectors and is affixed to sturdy beams within the hung ceiling of the room. As shown in Figure 6, three projectors are mounted on sliding brackets attached to a single rail, which extends most of the width of the room. This rail is attached via sliding mounts to two orthogonal rails, which allow the first rail to slide towards and away from the entrance and far wall. Projectors can be mounted to any of the rail components, allowing projection on to the side walls as well as the end wall.

![Figure 6 Projector railing system in the Intense Collaboration Space](image)

The configuration of the rails used (45 mm Unistrut C-channel) is not structurally strong enough to comfortably support three Mitsubishi XD300U projectors without deformation and so it bows slightly. Although this is visible to the naked eye, it only stands out significantly due to the way the projectors’ light falls onto the far wall. The small tilt is very obvious, as the projections do not meet neatly. Furthermore, because the room has a raised tiled floor, sudden movements can sometimes cause the frame to wobble slightly. This wobble is exacerbated in the projectors because the mounting mechanisms are not rigidly fixed.
The original intention behind the railing system in the ICS was to facilitate easy reconfiguration of the projected displays. As mentioned above, there has not yet been a need to test this. The deformations observed are primarily due to appropriate structural calculations and designs not being part of the construction process, and these are also seen in the HQ1Div frames. The lessons learned from these experiences resulted in sturdier projector support in the FOCAL frame, specifically by requiring a formal structural design for the frame as part of the SES work request.

3.2 Future Operations Centre Analysis Laboratory

In 2005 a Livespace housed in a frame was constructed (using similar Unistrut C-channel to that in the ICS) in the FOCAL, creating an opportunity to integrate the Livespaces technology with the Future Operations Centre concepts and technology existing already in FOCAL. A schematic for the layout of the FOCAL Livespace can be seen in Figure 7.

![Schematic diagram of the FOCAL CAT layout from an aerial perspective](image)

The frame itself consists of three modular sections, extra pillars on three of its sides (none on the side facing into the main FOCAL work area in front of the large semi-immersive display), and strengthening struts above head height to increase sturdiness (Figure 8). The non-symmetrical nature of the frame design is a reflection of the specific environment for which it was crafted.
Despite the frame being reinforced above head height and at ankle height in those parts where people do not need to walk, the frame is easy to shudder if jolted. This effect may be reduced by bracing the frame more securely to the surrounding structures. The floor in the laboratory is also not very stable and can quake if someone jumps up and down a few times. The quivering of the frame causes the projectors and whiteboards to quiver perceptibly. The entire frame is rated to carry a load up to 130 kg, which limits the number and types of devices that can be hung from it.

Attached to this frame are two Mitsubishi XD300U projectors, which project onto two 1600 × 1200 mm whiteboards on a rail system that is mounted on the back of the frame. Three webcams are also mounted on the frame in various locations for video teleconferencing. The mounting mechanisms used for the projectors are significantly different from those in the ICS (see Figure 9), consisting of a bracket that firmly bolts the projector to the frame, rather than allowing it to hang off rollers for reconfigurability. Cabling for the devices is run along the channel of the frame.
Figure 9  A cross-section view of the FOCAL projector mounting system, now in use in the ICS
4. Statement of Requirements

Each of the requirements in the *Statement of Requirements* developed for SES and listed below has been either fulfilled or accounted for. During the design and construction it became apparent that some requirements were too costly, contradictory or impractical and so required modification, and also trade-offs were made where two feasible requirements competed (e.g. due to physical constraints or prohibitive cost). This list of requirements was based on an original list which did not consider costs.

The requirements are presented in this section, but are referred to individually in Section 5 where the CAT is described in detail. Section 5.5 on page 29 gives a complete summary of these requirements and their status at the conclusion of the project.

4.1 Frame Requirements

1. The frame must be set up within a weatherproof enclosure such as a tent, hut, shed, warehouse, or other suitable accommodation.
2. The frame must be modular with increments of two metres (i.e. use components of modular lengths and an interconnection system).
3. The frame must be suitable for a duty cycle of repeated assembly/disassembly.
4. The frame must be able to be erected or dismantled by one man in four hours.
5. The minimum workspace size must be approximately 3.1 × 3.1 m.
6. The frame must be totally independent of the tent or other accommodation in which it is erected.
7. The basic floor plan shape must be either square or rectangular with capacity for modular expansions in any horizontal direction.
8. The frame must be light weight (N.B. the expense of aluminium is acceptable).
9. The frame must carry a range of equipment safely and with stability. (The equipment inventory and frame rigidity or stiffness shall be quantified.)
10. The frame must be of acceptable aesthetic appearance.
11. The frame must accommodate provision for a false floor option.
12. The frame must accommodate routing and enclosure for all wiring, wiring interconnections and outlets.
13. The frame and wiring enclosure system must be designed to facilitate wiring and installation of communication equipment by one man in four hours.
14. The frame system must be able to be disassembled into components rather than panels.
15. The disassembled components must suit packaging into minimal volumes and shapes to facilitate storage and transport.
16. The frame components must be designed to be stored and transported on a standard Army pallet, 1800 × 1800 mm in size, and the existence of longer or alternative storage and transport options should be explored.

17. The frame must accommodate mounting of pinboard panels (spanning the entire distance between columns).

18. The frame must be designed to cater for a minimum of skills and training for competent assembly/disassembly.

19. SES must provide straightforward assembly instructions for the frame.

20. The frame may be either a COTS or custom-designed system.

4.2 Subsequent and Other Requirements

A. Specialist folding furniture has been designed and built for use in the Livespace environment. SES must document this furniture for re-manufacture and also design/select packaging containers for this furniture.

B. SES must compile an inventory of all Livespace environment equipment/devices and design/select packaging for this equipment.

C. The frame materials and packaging selections must be durable enough for an Army field use environment, including abrasion from extensive handling.

D. The frame must be able to cope with occasional wetting.

E. The frame must be able to cope with a considerable temperature range.

F. The frame must be constructed entirely from within, assuming no space is available outside the frame so that the most can be made of any available environment.
5. Description of the CCSL CAT

This section describes the various components of the CAT as it stands currently. There is some discussion of how or why various choices were made, but the majority of that content can be found in the next section, along with recommendations arising from the experiences. Which requirements various components attempted to address is included after each paragraph in this section.

5.1 Frame

SES was instructed to undertake a survey of applicable framing materials and structures as part of their role in identifying and supplying a suitable framing approach to meet the requirements. SES recommended the Octanorm framing system as the most suitable, given time critical constraints. Although it is most often used for stands and displays at expos and other short-term events it is highly reconfigurable and suited to frequent redeployment and was considered the best. The main structure of the CAT is made from Octanorm aluminium extrusions. The configuration of the frame uses four (with two variations on one) types of Octanorm beam component and two sizes of Octanorm T-bolts (with associated nuts and wingnuts). In addition to this SES produced aluminium struts used as horizontal supports on which to mount pinboards and whiteboards. [Requirements 3, 8, 10, 14, 15, 18, 20]

The frame is formed as a 3x4 modular arrangement (based on wall modules), with single beams traversing the shorter dimension as the ceiling (Figure 10). This leaves space for the other ceiling beams (orthogonal to the first described) to be arranged according to requirements regarding the devices to be mounted on the ceiling. Each module is large enough to comfortably handle pinboards and whiteboards 1600 mm wide (a module is based on two 80 × 80 mm columns and a horizontal beam 1550 mm wide). [Requirements 2, 5, 7, 9, 14, 16, 17]

![Diagram of the frame](image)

*Figure 10* A 3D schematic of the frame to house the CAT, as designed by SES with customised Octanorm components. Non-structural ceiling beams are floating and can be moved.
The frame was constructed entirely within the CCSL room and takes up almost all the available space (see Figure 11). There is an average 250 mm gap between the room walls and three sides of the frame, although this varies a little because the walls and floor of the room all were found to have slight curves and distortions (an inward curve of approximately 50 mm over the length of the room are observable on the Southern wall). The adjustable feet on the bottom of the frame columns coped easily with the variation in the floor. Clearance to the ceiling is 50 mm in most places, so it was necessary to remove ceiling tiles to complete the construction. [Requirements 1, 5, 6, 7]

Devices can be attached to the Octanorm beams either with their own clipping system (as with the SES-designed light mounts) or with Octanorm T-bolts that slip into place in the slots along the Octanorm beams but which fall out unless a nut is used to tighten them (see Figure 12). [Requirements 3, 9, 14, 7, 18, 20]

The initial construction time for just the frame alone took two SES staff three days to complete, although extra help was required on a few occasions to lift some of the larger beams and intermediate structures. Much of this time was spent experimenting with different procedures, however, and it was found that if mounting locks can be added to the frame components during manufacture, construction time can be reduced significantly. The horizontal struts also took approximately eight to ten hours (with two people) to mount to the frame. By using wingnuts instead of typical nuts it may be possible to reduce this time also as the normal nuts were awkward to use, although the use of a low-torque electric screwdriver could also improve installation speed. Alternative methods for mounting wall cladding may also require less time to construct (see the next section for more detail). [Requirements 3, 9, 14, 17, 18]

Once constructed the frame is extremely strong and far sturdier than the FOCAL frame. The heaviest device attached to the frame is the electrical distribution board, which weighs
approximately 40-50 kg. It is attached to part of the frame by four M8 T-bolts with no visible stress to the frame. [Requirement 9]

In order to ensure that the frame was able to support the weight of multiple devices, such as projectors, projection screens, distribution boards and access panels, the beams obtained are rated to support 135 kg in their centre. Future, more stringent, requirements may require extra strength. [Requirement 9]

For flexibility extra ceiling beams were purchased, which can be moved after installation if other devices need to be attached in new locations. The only caveat is that these kinds of beams must be introduced at the time of installation and cannot be inserted once the frame is erected due to the mechanism of attachment. These beams can only be slid into a new position (see Figure 13). Alternative, custom-made beams and attachments may be used in place of Octanorm beams to overcome this limitation, but this was not investigated in this iteration. [Requirements 14, 19, 20]
5.2 Access to Power and Data

Access to power and data in the CAT is provided via custom-built access panels, which are, to the greater extent, over-sized power boards with network and USB connectors. Wiring is able to be easily plugged into these with standard components, and each access panel is supplied with power from a central custom distribution board, which also houses a Clipsal C-Bus controller for controlling lights and motorised projection screens. Five access panels are arranged around the frame near ground level and one is mounted in the ceiling to provide power and data to ceiling mounted devices such as projectors. The cabling used includes power, audio, and CAT5e and CAT6 (untwisted pair cabling is used for network access, USB extension, and audio/video matrix data). Furthermore network access is daisy-chained between the access panels, so only one cable goes back to the rack, rather than one per access panel (see Figure 14) greatly reducing cabling access requirements. In retrospect, it is not clear that CAT6 cabling offers any great advantage to us than CAT5e with the current requirements. CAT6 cabling is significantly more expensive than CAT5e and is not as mature a technology, although it ensures our systems are ready for future unforeseen requirements. [Requirements 6, 12, 13, 16, 18, 20]
Power is designed to be provided to the access panels via extension cables running from the central distribution board (although the access panels can be powered from wall sockets if available, as shown in Figure 15). The central distribution board has five circuits, each of which can power at least one access panel and has its own circuit breaker. The first circuit also supplies power to the Clipsal C-Bus unit. In turn, the C-Bus controls the banks of lights via typical power cables with three-pinned plugs and the motorised projection screens with special four-pinned plugs. Several repairs were made to the C-Bus relay component controlling the motorised projection screens until 20A relays were used (the 10A ones kept fusing). If more fusing problems occur a soft-start relay alternative may be considered. [Requirements 12, 15, 20]

Two open 75 mm Oziduct channels run around the outside of the frame, supported by 160 mm Octanorm extrusions attached directly to each of the Octanorm columns (Figure 15). The outer of the two channels is bolted to the extrusions to avoid slippage. Power cables are placed in one of the channels and data cables in the other. This is suitable for RESTRICTED data cables but may not be for higher classifications. A simple solution is to use other extrusions at different heights to separate the channels. [Requirements 12, 20]

5.2.1 Access Panels

Each access panel (shown in Figure 16, Figure 17, and Figure 18) is a custom-built box fabricated by SES and kitted out by our electrical and data cabling contractor. They house power, network, USB, and audio connectors, and have standard sockets for feeding the board on one side and accessing its features on the other. Each access panel provides the following ports:

- 12 network ports + two dedicated for IPLink devices\(^2\) (though they could be used simply for network connectivity)
- three 3.5 mm stereo audio ports
- three RJ45 connectors for audio/video connections (or any type of data that can be extended over CAT5e cables)
- one USB connector for powered USB 2.0 devices (the transmitter component of a USB-over-CAT5 extender with the corresponding receiver device located in a server rack)
- six 10A power points on the front (plus two on the rear of the unit).

[Requirements 2, 3, 12, 13, 14, 15, 16, 18, 20]

On the rear side are male and female 10A power sockets (one male for feeding power to the unit and two female for power access), three stereo 3.5 mm sockets for audio cabling, one RJ45 socket for the USB2.0-over-CAT5 extender, three RJ45 sockets for audio/video over CAT5, in and out RJ45 ports for network access and daisy chaining, and an ammeter for checking how much power is being drawn by devices connected to the access panel. [Requirements 2, 3, 13, 14, 15, 16, 18, 20]

Figure 16  Schematic of the front and back of the access panels highlighting requirements

Figure 16 shows the schematic diagrams of the front and back of the access panels to indicate our general requirements. Figure 17 shows an internal cross-section of the access panels to indicate how the wiring could have been arranged. Figure 18 shows the front and back of the delivered access panels.

Figure 17  Schematic of the cross-section of the access panels highlighting requirements
Power for these boards can be provided by standard 10A power extension leads. These leads can be directly connected to available wall sockets or to the distribution board, but care should be taken to note which circuits are powering which boards. [Requirements 2, 13, 14, 15, 16, 18, 20]

5.2.1.1 Mounting of Access Panels

Two distinct mounting mechanisms were required for the access panels due to the fact that five panels are mounted in the lower pinboard panels around the workspace and one is mounted in the ceiling. The lower access panels are slotted into the holes in five of the pinboards, the bottom of which line up exactly with the lower horizontal Octanorm beam, meaning that the majority of the weight of the access panel is supported by the Octanorm frame. To ensure these panels do not fall out, however, especially given cables will be plugged into and pulled out from the panels, special clips were designed to hold them in place (see Figure 19). [Requirements 2, 12, 13, 14, 15, 16, 18, 20]
For the panel mounted in the ceiling a different mechanism was required. Strips of 3 mm aluminium with slots cut in them were made which span the arbitrarily sized gap between the Octanorm ceiling beams (the slot allows for variation in the gap). The panel rests on and is bolted to the strips. The strips are strengthened by folding an edge, turning them into pieces of angle. The resulting support strips are shown in Figure 20. [Requirements 2, 3, 8, 9, 12, 13, 14, 15, 16, 18, 20]

![Figure 20](image)

**Figure 20** Two photos of angled support struts for mounting devices to the ceiling of the frame. On the left is a close-up view of a strut, with the attachment slots clearly visible. On the left, an access panel is mounted in the ceiling of the frame by resting it on and bolting it to the struts that are bolted to the underside of the frame.

5.2.2 Distribution Board

The distribution board is a 1200 × 600 mm COTS item made from steel (see Figure 21), though a custom-built model could be constructed from aluminium to reduce its weight. It is attached by four M8 T-bolts to horizontal Octanorm beams on one side of the frame, and was kitted out once it was attached. It was very heavy before it was kitted out needing two people to hold it in place to install it, so it will require a significant amount of care to remove it. Changes to how it is attached will also make it easier to mount to or remove from the frame in future. [Requirements 2, 3, 6, 12, 13, 14, 15, 16, 18, 20]
Figure 21  The distribution board houses five separately powered circuits. The first circuit powers the Clipsal C-Bus system and its devices (lights and projection screens) and the other four circuits are for powering up to four of the six access panels.

As described in our specifications (Figure 22) it houses five banks of four 10A power points with ammeters and circuit breakers. Each bank is supplied with power via a 15A male socket at the base of the board. One bank also supplies power to a Clipsal C-Bus unit. The C-Bus provides connectors for three motorised projection screens, three banks of fluorescent lights and three banks of spotlights. There is space in the C-Bus unit for many more relay and dimmer devices, and a smaller system could be used in future, depending on what flexibility in device control is required. The same bank also provides power to a C-Bus control panel for manipulating some of the C-Bus devices (lights and projection screens). Although requirements specified an Ethernet-based PC-Interface component a RS-232 Serial component was provided and was deemed acceptable. [Requirements 2, 3, 6, 12, 13, 14, 15, 16, 18, 20]
5.2.2.1 Mounting of Distribution Board

The strength of the Octanorm components was relied upon to mount the distribution board. The board is attached to two horizontal 80 × 80 mm Octanorm beams with Octanorm 8M T-bolts.

5.3 Pinboards and Whiteboards

The Octanorm frame creates a space with 14 modules (three modules on two opposite sides and four on the remaining sides). With the addition of SES-designed and built horizontal support struts the modules each have two small pinboards (1600 × 770 mm) and one large whiteboard (1600 × 1200 mm), giving the effect of a pinboard wall with a whiteboard in the middle at a convenient height. When each module is arranged with boards in this way, it creates the effect of a single continuous whiteboard surrounding the workspace (with one module remaining open, as a doorway). Several of the lower pinboard panels have special holes cut in them into which the access panels are fitted. [Requirements 2, 3, 5, 7, 10, 14, 15, 16, 17, 18, 20]

Two substrates for the boards were considered, with the older Coreflute substrate being used on the majority of boards due to time constraints. A new, much lighter material, known as paper foam, became available during the project and so it was difficult to obtain a sufficient amount of it for our purposes. The difference in structure between the two substrates is shown.
in Figure 23 below. The Coreflute is prone to bowing and is significantly heavier than the paper foam material, which consists of layers of fine foam interleaved with a plasticised paper product. It was hoped that the paper foam substrate would bow less and make the boards significantly lighter; however this has not been the case. Large pinboards made of paper foam have bowed much more than the Coreflute pinboards as the fabric glue has dried and contracted. The Coreflute has more integral strength and is better at maintaining its shape. Whiteboards made of paper foam are just as heavy as the Coreflute ones, due to the majority of the weight coming from the sheet metal of the whiteboard surface. The paper foam appears to be the best option for the small pinboards, however, as they are much lighter than the Coreflute ones and are not big enough to bow significantly. Fire safety information has been obtained showing it to be consistent with Defence regulations. [Requirements 8]

![Figure 23](image)

**Figure 23** Substrate structures considered for the whiteboards and pinboards. *a)* is the Coreflute material, essentially a plastic cardboard. *b)* is the paper foam substrate, with layers of paper interspersed with a plastic foam.

In order to avoid interruption of the pinboard or whiteboard material, coupled with the restriction that the frame and its components be constructable entirely from the inside (i.e. no access to behind the walls during construction), a novel method of attachment was devised. An extra requirement was that lower boards be able to be removed without the other boards falling off, for safety. The solution was to use a selection of Velcro swatches on the backs of the boards, with much of the boards' weight being held by the boards below (with the bottom board supported by a special horizontal strut with a shelf) (see Figure 24). [Requirement F]

Swatches of Velcro are attached to the horizontal support struts and the backs of the pinboard and whiteboard panels. The horizontal struts are wrapped (vertically) with the hook side of strips of 50 mm wide Velcro to ensure maximum coverage, with the ends of the Velcro being riveted in place (experience has shown that the glue tends to give way and shear after a short period of time). Corresponding 50 × 50 mm swatches of Velcro (the loop side) are riveted to the backs of the pinboards and whiteboards. To aid with this type of attachment, the whiteboards are backed with strips of tin, which holds the rivets better than Coreflute or paper foam alone. Along the edge of the whiteboards, the swatches are riveted directly to the protective edging angle that extends in by 50 mm (see the paragraph after the next). In the case of the pinboards, the swatches are riveted through the fabric wrapped around the edges of the boards. An alternative is to rely on the fabric itself as the ‘loop’ side of the Velcro, as it pills very little and could work quite well, providing that sufficiently strong glue is used and
that the fabric wraps a considerable distance (100 mm or more) in from the edge of the boards. The Velcro swatches need to be large to counter the natural bowing of the boards. [Requirements 8, 17, 20, F]

Figure 24 The mechanism by which whiteboards and pinboards are attached to the frame. Horizontal struts made of aluminium are bolted to the inside of the columns. These are lined with Velcro and the corresponding Velcro swatches are attached to the back of the boards.

A snug fit between boards arranged vertically is achieved by attaching lower boards before upper boards. Similarly a snug fit is achieved horizontally by ensuring that each next board snugly abuts the board before it. The use of Velcro as the attachment mechanism means that there is flexibility in the exact attachment position. There are some minor discrepancies between panels on adjacent modules (5 mm or less), but this is an acceptable error, given that it represents significantly less than 1% of the width of the boards. Furthermore, the board size chosen has ensured that any gaps at corners of the frame are less than an inch and so the appearance is that of a fully solid wall all the way around the workspace. [Requirements 8, 17, 20, F]

To ensure a minimal border interruption between the writing surfaces of adjacent whiteboards, creating the effect of a single continuous whiteboard around the workspace, while protecting the edges of the whiteboards from splitting and other damage, the whiteboards are edged by 12 × 50 × 1.2 mm pieces of angle which are riveted to the substrate and provides protection right up to the edge of the writing surface. Due to the effectiveness of
rivets in the Coreflute and paper foam materials it is necessary to also glue the angle down with very strong glue. [Requirements 8, 17, 20, F]

With regard to the constructions of the pinboards, the covering fabric wraps all sides by 100 mm to ensure a good attachment. Those boards with holes in them have pinboard fabric wrapped into the hole by 50-100 mm, which was appropriate for our requirements. [Requirements 12, 13, 14, 15, 16, 17, 20, F]

5.4 Mounting of Devices

Designs for mounting specific devices to the frame were developed by SES with some consultation with research staff and inclusion of off-the-shelf mounting components. Mounting was required for Mitsubishi XD300U projectors, ScreenTechnics projection screens (sizes 2240 × 3985 mm and 1100 × 1465 mm), as well as standard down-lights and fluorescent lights. [Requirements 2, 3, 6, 20]

Projectors are mounted using ScreenTechnics spider brackets3 (see Figure 25.a) attached to SES-designed mounting brackets (Figure 25.b), which make detaching and re-attaching projectors relatively easy (compared to those in the ICS and FOCAL). The ScreenTechnics spider brackets allow projectors to be held in place in a ball joint while a large nut is screwed tight to keep the device in place. [Requirements 2, 3, 6, 20]

![Figure 25](http://www.screentechnics.com.au/Site/Default.asp?Site=OZ&XML=Product_1014.xml&XSL=Products.xsl&Browser=other)

**Figure 25** The projector mounting system consists of a) a ScreenTechnics 'spider' projector bracket, which attaches to the underside of b) a SES designed bracket which attaches to a 160 × 80 mm Octanorm beam

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The ScreenTechnics projection screens have specific mounting points, which allowed SES to design simple but effective brackets for mounting the screens to the frame making use of the mounting slots in the Octanorm beams (see Figure 26). Although subsequently discovered to be unnecessary, these brackets provided mounting space for ScreenTechnics’ CD4 devices, which provide an integration point with building management systems (such as Clipsal C-Bus). It was discovered that the Clipsal C-Bus system can interface directly to the projection screen motors with standard relay components, although it was found that the 10A relays would short circuit after a short period of use, so 20A relays were used. [Requirements 2, 3, 6, 20]

The most customised mounting devices were developed for the down-lights and fluorescent lights. These mounts (shown in Figure 27.a) are sheets of folded aluminium which clip into the slots in the Octanorm frame (shown in Figure 27.b) and provide a mounting location for the lights, as shown in Figure 27.c and Figure 27.d. Due to the simple nature of this mounting design, it is ideal for a variety of different devices, and even has been used for supporting the PVC channel running around the outside of the base of the frame for holding power and data cables. [Requirements 2, 3, 6, 20]
5.5 Summary of Requirements Addressed

Each of the requirements in the Statement of Requirements developed for SES to use has been either fulfilled or accounted for as described above. This summary of those requirements provides more insight into the justification of the status of each requirement and how it was fulfilled or why it was discarded, details that were not appropriate for the scope of the preceding subsections.

5.5.1 Requirements

1. The frame must be set up within a weatherproof enclosure such as a tent, hut, shed, warehouse, or other suitable accommodation.  
   **Status: Achieved.** The frame constructed is currently housed in 2.G.58 of 205 Laboratory at DSTO Edinburgh, but it could be housed within a large tent or a warehouse, provided sufficient space and electricity is available.

2. The frame must be modular with increments of two metres (i.e. use components of modular lengths and an interconnection system).  
   **Status: Achieved, Modified.** The module size is 1.63 m, primarily guided by the space
available in room 2.G.58 and standard pinboard sizes. The Octanorm system allows for interconnection between modules.

3. The frame must be suitable for a duty cycle of repeated assembly/disassembly.  
**Status: Achieved.** The techniques and materials used have been designed for repeated assembly and disassembly.

4. The frame must be able to be erected or dismantled by one man in four hours.  
**Status: Discarded.** This requirement was discarded due to physical impossibility. The size and complexity of the CAT necessitates the provision of at least two people for construction (plus one or two more during the initial part of the frame construction phase) and it will take several days to construct. Construction time may be reduced by the addition of extra people, but various components must be installed in order (e.g. the whiteboards cannot be installed until the frame is erected and struts affixed), meaning a construction time of four hours is impractical.

5. The minimum workspace size must be approximately 3.1 × 3.1 m.  
**Status: Achieved.** The size of the frame is approximately 6.5 × 5 m and may be increased in size in at least one dimension.

6. The frame must be totally independent of the tent or other accommodation in which it is erected.  
**Status: Achieved.** The CAT is entirely independent of its environment except that it requires power and shelter from weather (and some clearance is required during construction and maintenance).

7. The basic floor plan shape must be either square or rectangular with capacity for modular expansions in any horizontal direction.  
**Status: Achieved.** The CAT constructed is rectangular in nature, being 3 × 4 modules in arrangement with a height of approximately 3 m. With some component redesign it could be made wider or deeper.

8. The frame must be light weight (N.B. the expense of aluminium is acceptable).  
**Status: Achieved, Modified.** The Octanorm frame and many components are constructed of aluminium in the cases where they are made from metal (as opposed to e.g. plastic). Other components are constructed of light materials (e.g. the paper foam substrate for the pinboards and whiteboards). Due to the sheer number of components, however, the total weight of the CAT is not insignificant. Each component, except for the long Octanorm ceiling beams and the distribution board can be carried by a single person.

9. The frame must carry a range of equipment safely and with stability. (The equipment inventory and frame rigidity or stiffness shall be quantified.)  
**Status: Achieved.** The Octanorm frame is sufficiently sturdy to easily support motorised projection screens, projectors and sound-deadening curtains. The longest beam is rated to carry at least 135 kg at its centre.

10. The frame must be of acceptable aesthetic appearance.  
**Status: Achieved.** The Octanorm frame is a pleasant brushed metal colour in appearance. The pinboards delivered are an acceptable grey/blue in shade.

11. The frame must accommodate provision for a false floor option.  
**Status: Achieved, Modified.** The requirement for a false floor was removed in the interests of speedy construction and practicality. A false floor could be added within the frame itself (e.g.
12. The frame must accommodate routing and enclosure for all wiring, wiring interconnections and outlets.  
**Status: Achieved.** The CAT has access panels and a distribution board for wiring connectivity and cable channels surrounding the frame for cable management.

13. The frame and wiring enclosure system must be designed to facilitate wiring and installation of communication equipment by one man in four hours.  
**Status: Achieved.** Once the frame has been constructed and the panels and devices installed, laying the wiring and connecting the devices should be achievable within this timeframe (though this has not been tested).

14. The frame system must be able to be disassembled into components rather than panels.  
**Status: Achieved.** The CAT delivered can be disassembled into components.

15. The disassembled components must suit packaging into minimal volumes and shapes to facilitate storage and transport.  
**Status: Achieved, Modified.** All components except for the large room-spanning Octanorm beams and the distribution board are small enough to be carried by one person, though no experimentation with packaging was carried out.

16. The frame components must be designed to be stored and transported on a standard Army pallet, 1800 × 1800 mm in size, and the existence of longer or alternative storage and transport options should be explored.  
**Status: Achieved, Modified.** All components, except the large room-spanning Octanorm beams and columns, are smaller than 1800 mm in all directions, though no experimentation with packaging was carried out.

17. The frame must accommodate mounting of pinboard panels (spanning the entire distance between columns).  
**Status: Achieved.** All internal walls of the CAT are covered with pinboards and whiteboards.

18. The frame must be designed to cater for a minimum of skills and training for competent assembly/disassembly.  
**Status: Achieved.** All frame components can be assembled with wingnuts and the Octanorm Allen key tool. Whiteboards and pinboards are put in place with Velcro. Lights are mounted with a clip-in system. Projection screens are bolted in place. Wiring between the access panels, distribution board and devices is arranged with RJ45 connectors and three- or four-pinned power plugs.

19. SES must provide straightforward assembly instructions for the frame.  
**Status: Achieved.** Assembly instructions are included in the SES documentation package Z8431 and assembly instructions are included on diagram 472D271101 (sample 3D drawings of the frame component can be found in Appendix B).

20. The frame may be either a COTS or custom-designed system.  
**Status: Achieved.** The CAT delivered is a custom-designed system made from COTS products. The mounting and access panel components are custom-designed and fabricated by SES.
5.5.2 Subsequent and Other Requirements

A. Specialist folding furniture has been designed and built for use in the Livespace environment. SES must document this furniture for re-manufacture and also design/select packaging containers for this furniture.

**Status: Discarded.** There was no furniture to document at the time of the work.

B. SES must compile an inventory of all Livespace environment equipment/devices and design/select packaging for this equipment.

**Status: Discarded.** There was no equipment to document at the time of the work.

C. The frame materials and packaging selections must be durable enough for an Army field use environment, including abrasion from extensive handling.

**Status: Discarded.** The Octanorm frame is designed for repeated handling and transport but effort for considering Army field use was ultimately beyond the achievable scope of this project, and repeated construction and transport has not been tested. Other equipment is easy to handle and sufficiently durable or easy to replace that it could be ready for field use, but this also has not been tested.

D. The frame must be able to cope with occasional wetting.

**Status: Discarded.** The CAT has not been weather-proofed.

E. The frame must be able to cope with a considerable temperature range.

**Status: Discarded.** Being made of aluminium, the frame is able to withstand a broad range of naturally-occurring temperatures. Pinboards, whiteboards, and other equipment should also be able to cope with a broad range of naturally-occurring temperatures, though perhaps not extreme temperatures. In any case, this requirement extended beyond the scope of the project.

F. The frame must be constructed entirely from within, assuming no space is available outside the frame so that the most can be made of any available environment.

**Status: Achieved.** The use of Velcro-based mounting mechanisms to affix pinboards and whiteboards to the frame walls avoided the requirement for workmen to move around outside the frame during construction.
6. Lessons Learned

During the exploratory construction of the CAT, it became apparent very quickly that there were better ways to do things and that it would be valuable for these lessons to be recorded and reported on for future constructions. By taking these recommendations into account, the design, construction, and procurement processes for new CATs will be improved. Most recommendations will be applicable regardless of specific requirements.

Recommendations are shown in grey boxes and are numbered RX for referencing, and a complete list can be found in Appendix A. Recommendations are made following discussion of particular lessons learned or experiences.

6.1 Frame

The Octanorm frame is an ideal product for our purposes and certainly worth the cost due to its flexibility and strength. The Octanorm representative was exceedingly cooperative and supportive despite frequent changes in requirements and he has consistently provided excellent service and a very competitive price. Octanorm was been particularly flexible in supporting our changing requirements, and it is important that tenders for similar work on projects with ill-defined initial requirements include criteria for vendor flexibility.

| R1: | Consider Octanorm as a frame vendor when frame system requirements include high frequency of assembly and disassembly. |
| R2: | Tenders for exploratory projects in the future should include selection criteria for flexibility in working with changing requirements. |

A number of lessons have been learned regarding the products available from a variety of vendors. If hand measurement is required for installation (e.g. aligning components before fastening them together), a small set of gauges was found to be an effective and inexpensive way to ensure the correctness of measurements. A better solution, if working with Octanorm (and other vendors may support this), which would also speed construction, is to specify attachment points to the vendor during the design process and use Secure Tension Locks4 or similar products to ensure precise and very strong attachments for quick and easy installation.

| R3: | Design the frame in detail and use Secure Tension Locks, or similar technologies, where possible and the more flexible floating (typical tension lock) mechanism only where such flexibility is required. |
| R4: | Design the frame according to the requirements of the users, to avoid overspecification and extra cost. |

There were no noticeable macro-level improvements apparent after the process of frame construction was completed. Perhaps more practice will highlight some minor improvements. In retrospect a laser line tool would have been a inexpensive and useful addition for ensuring...

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4 Secure Tension Locks (STLs) are a hook and slot arrangement that can be tightened, shown in the top right corner of Figure 12.
the frame was square. A locking mechanism in the column foot adjusters would also be useful to aid with keeping the frame square.

| R5: Obtain a laser line tool for ensuring the frame is square. |
| R6: Add a locking mechanism to the column foot adjusters during the design and quoting phase. |

Although the frame was designed to be constructed from within, the practice is awkward and construction from the outside of the frame would be a lot easier and offer the opportunity to use different attachment methods. It is recommended to allow more space than 400 mm around the outside of the frame and at least 200 mm above it. It would be possible to build the frame with only 50 mm headroom but it would require custom tools and would be very awkward.

| R7: Construct the frame in a space at least 1500 mm wider and deeper than the frame, and with 200 mm space above the frame. |

To ensure that the frame's structural integrity was maintained while providing points for ingress and egress, we used a second horizontal supporting beam across the top of the 'door' (see Figure 28). A beam creating a doorway 2.08 m tall was found to be suitable.

![Figure 28 A doorway in the Octanorm frame](image-url)
DSTO-TR-2466

R8: Ensure a beam other than the ceiling beam is used to maintain structural integrity in 'doorways' in the Octanorm frame.

New CATs may have different requirements that require different designs. If weight is an issue then narrower Octanorm beams can be used. If packaging size is an issue, then the large beams we have used to span the frame may be split, but this reduces their strength significantly.

R9: Use thinner, narrower Octanorm beams if weight is an issue, recognising that the thinner beams will not be able to support as much weight.
R10: Split long Octanorm beams if size an issue as long as the reduction in frame strength is accounted for.

Although initial requirements stated that the frame be able to be assembled by one person, other requirements have meant that at least two people are required for the assembly and, in some circumstances, one or two more than that. Even with this small number of people a CAT is expected take some four or five days to construct (though this has not been tested). When detailed construction procedures are specified and the construction process has been conducted several times, it may be possible to specify during which phases more or fewer people are required. This is referred to again in Section 6.12 regarding construction practices.

It was decided that the requirement for a raised floor be removed due to conflict with the goals of the project. A raised floor would require highly customised components and significant effort to set up. Floor tiles made for a 3 × 4 frame would not fit in a 2 × 3 frame and still fit snugly against the (3 × 4) frame (avoiding any gap between the frame and the raised floor down which small items could fall as well as being a safety hazard). Also, to ensure a perfectly flat floor a laser levelling device would have been required to ensure that all floor supports were correctly configured. In the interests of construction speed, the raised floor was regarded as a low-priority requirement, and ultimately dropped altogether.

6.2 Horizontal Struts

Much of what was learned regarding the use of the horizontal struts involved how they are mounted to the Octanorm frame and how the whiteboards and pinboards are mounted to them.

The earliest lesson learned concerned the types of nuts used to attach the struts to the frame. Two battery-operated drills were purchased before the frame equipment arrived to be used during construction, which were subsequently found to be unnecessary: M5 and even M8 nuts could be tightened by hand and small wrenches sufficiently tightly to not require powered assistance. M5 nuts are small and fiddly to work with, however, so wingnuts were purchased half-way through construction. Wingnuts are a lot easier to manipulate and tighten by hand and can still be tightened further with a shifter wrench if necessary. Small low-torque electric screwdrivers could be used instead, which may increase installation speed but this option was not investigated. It is possible that even small screwdrivers might not have fitted conveniently where needed to tighten the nuts, leaving manual tightening as the only option.
**R11:** Use wingnuts wherever possible (and appropriate) instead of normal nuts.

Related to how the struts are mounted is the issue of coordinating attaching pairs of Octanorm T-bolts while simultaneously positioning the strut. Because the bolts fall out of the slots unless the nut is tightened, it is difficult to tighten both bolts at each end of the strut sufficiently for them to hold, but for them to be loose enough to allow further positioning of the strut. Alternative flange designs on the struts may provide the flexibility required in this circumstance. The struts we used have two open slots (Figure 29.a), which makes it easy to slot them into place but difficult to maintain sufficient hold on the bolts that they do not fall out while positioning the strut. A closed slot (Figure 29.b) would make it awkward to put the strut in place because the flanges on both ends of the struts would need to be pulled back to allow them to get into position. An alternative design yet to be tested is a zigzagged slot (Figure 29.c) which allows the strut to be put into place, but should provide enough support for the bolts to stay attached to the beam but not slide off the strut (if it twists).

**R12:** Consider using a zigzagged slot design with the strut flanges.

![Figure 29: Different designs for the strut flange slots: a) the current open slot design, b) the closed slot design, and c) the zigzagged slot design. These flanges are orthogonal to the face of the struts and are fixed to the Octanorm beams with Octanorm T-bolts through the slots. If a slot is closed it is hard to get bolts on both ends of the strut in place. If the slot is open, there is a risk that the strut will fall off one or both bolts during precise positioning.](image)

**R13:** Use a strut with an extended lip or one with a relieved flange to minimise the distance between the lower pinboard and the floor.

![Figure 30: Floor level flange designs, end on. Shown are: a) the current design, b) a strut with an extended lip, and c) with a relieved flange.](image)
Due to the height of the bottom of the Octanorm columns above the floor (they are supported by adjustable feet, up to 50 mm off the floor plane) and the requirement that the lower pinboards be very close to the ground (within 25 mm), it is necessary to redesign the floor level struts, so that the supporting lip is lower than it is currently. This is because the struts are prevented from being positioned lower by the base of the columns. Figure 30.a shows the current design, end on, and Figure 30.b and Figure 30.c show alternatives.

To increase surface area for the attachment of Velcro (mentioned in detail later) the struts should be increased in width from 80 to 150 mm. This also ensures plenty of contact area on both upper and lower boards to affix to the strut. To ensure that the Velcro does not give way due to the glue shearing off, the Velcro can be riveted in place. This was found to be effective, and provides a mechanism to counter the bowing of the boards as well as ensuring they stay attached. Part of the issue with the Velcro attachment is that although the glue must stick, it must still have more attachment strength than the corresponding Velcro swatches have to each other, to ensure that boards can be removed without detaching the glue and also without breaking the boards. An alternative to the use of large Velcro swatches is to use two orthogonal medium width strips of Velcro, one vertical (wrapping entirely around the strut) and one horizontal (across the back of the pinboards and whiteboards), as shown in Figure 31, but this may not prevent the bowing of boards as well as large swatches of Velcro. An industrial hook-to-hook Velcro may also be considered instead of standard Velcro. To further aid the Velcro supporting the vertical weight of pinboards and whiteboards pieces of 12 × 12 × 1.6 mm angle could be bolted (or riveted if bolting is too fiddly) to struts in strategic places. In this case, the purpose of the Velcro can be purely to hold the board back against the struts, rather than also providing vertical support.

Figure 31  The orthogonal Velcro arrangement to provide maximum surface area for glue adhesion, while keeping the Velcro overlap (i.e. where the hooks meet the eyes) to a comfortable minimum to ensure boards can be removed without damaging them (i.e. by bending and breaking)
R14: Increase the width of the struts to 150 mm.
R15: Consider bolting pieces of angle to the struts to provide vertical support to the attached pinboards and whiteboards, rather than relying on the Velcro swatches, especially for heavy and large boards.
R16: Consider using an orthogonal arrangement of Velcro to ensure flexibility of attachment and maximum adherence of the Velcro glue.
R17: Rivet Velcro to the boards and wrap the corresponding Velcro all the way around the horizontal struts for the best attachment.
R18: Use Coreflute as the substrate for the large whiteboards and large pinboards, and use paper foam for the small pinboards, if using those materials.

Increasing the width of the struts will result in less structural integrity, so sheet metal thicker than 1 mm should be used to make them. Using thicker metal sheet could also allow for a redesign of the struts to aid with stacking for transit. The increase in weight is likely not to be significant, and in any case will be outweighed by the benefits of ease of installation and packaging.

R19: Increase the thickness of the sheet metal used for the struts to 1.5 mm for increased strength.

Although packaging and transit of the CAT components has not been investigated in detail, one item that will warrant significant consideration is how to protect the Velcro swatches attached to boards. Protecting the Velcro will stop its effectiveness from being diminished through crushing and will prevent boards from sticking to each other during transit. In the next section it is suggested to attach the hook component of the Velcro directly to the pinboard fabric wrapped around to the back of a pinboard, which would allow struts and pinboards to be stacked without fear of them accidentally being stuck together.

The effect of environmental pressures, such as heat and humidity, on the Velcro fabric and glue has not been considered but should be when constructing a CAT that will be used in the field.

R20: During the design process, consider environmental effects on the CAT components, especially Velcro, glue and pinboard fabrics.

An alternative idea for mounting the boards was considered during post-construction debriefing, one that might suit constructions with different requirements (see Figure 32). Brackets consisting of wide strips of aluminium with supporting lips at the bottom would be attached to the Octanorm ceiling beams (as the projection screens are currently mounted). To these vertical brackets could be attached pinboards and whiteboards and supporting angle with Velcro and bolts. Once constructed, a wall panel of two (or three) vertical brackets and pinboards and whiteboards could be managed as a single unit and simply hung up during construction.
Figure 32 This diagram shows an alternative board mounting idea. Strong brackets hang down from the ceiling beam (similar to the projection screen brackets), supported from behind by horizontal aluminium struts. These brackets have angle attached in specific locations to support each attached board’s vertical weight, and Velcro strips run down their entire length. The boards themselves (pinboards and whiteboards) will have strategically placed Velcro swatches. Construction is very simple, consisting of attaching the horizontal struts, then bolting on the vertical brackets, then placing the boards.

6.3 Pinboards and whiteboards

Although the new paper foam substrate was initially deemed preferable to the Coreflute material, due to time pressures the majority of pinboards and whiteboard delivered were constructed from Coreflute. They were delivered on a 1200 mm wide pallet, which caused the ends (given they are 1600 mm wide) to bend and the boards have subsequently kept their bow (making consistent attachment with minimal Velcro difficult). Coreflute is significantly heavier than the paper foam substrate, so it was thought that paper foam should be used exclusively as the substrate for boards in the future. When new large (1600 × 1200 mm) whiteboards and pinboards made with the paper foam substrate arrived however, it quickly became apparent that a combination of paper foam and Coreflute boards would be more suitable. The paper foam whiteboards were just as heavy as ones made with Coreflute (due to the amount of metal sheet used in construction) and both types of board bow. The paper foam pinboards bowed a great deal, probably due to the drying fabric glue contracting. The Coreflute pinboards of the same size did not bow nearly as much. The small (1600 × 770 mm) paper foam pinboards do not bow significantly and are much lighter than the Coreflute versions.
R21: Use paper foam substrate for small (1600 × 770 mm) pinboards and Coreflute for large (1600 × 1200 mm) pinboards and whiteboards.

To ensure that the pinboard fabric stays attached, it should wrap around the edges of the pinboards by a significant distance (at least 100 mm). We found that the pinboard fabric peeled when it was only wrapped around by 20 mm or less (Figure 33). Wrapping it in this way also allows it to be used with Velcro for attaching to struts. Vertiface or RimTechnic fabric should not be significantly affected by use in this way. The Prelude fabric will be affected by using it with Velcro though, according to the pinboard and whiteboard manufacturer. For one week we experimented with this idea by reversing a small pinboard so that it was attached by the fabric on the front directly to the Velcro on the horizontal struts: it did not fall, nor move at all, and when removed the fabric did not pill and appeared intact.

Figure 33  Pinboard fabric becoming unstuck from the back of a pinboard due to poor glue and the proximity requirements for the tin strips on the back of the pinboards

R22: Wrap pinboard fabric around pinboard edges by at least 100 mm.
R23: Use Vertiface or RimTechnic pinboard fabric.
R24: Use the wrapped component of the pinboard fabric to attach to hook Velcro on the struts when mounting.

The 20 × 12 × 1.6 mm angle riveted to the edge of the Coreflute whiteboards easily bent away from the boards and the rivets pulled out of the substrate. It is not expected that the rivets will hold any better in the paper foam substrate. Using a deeper angle coupled with a strong glue was found to avoid these issues.

R25: Use 50 × 12 × 1.6 mm angle glued and riveted to the whiteboards to protect the edges.

A new design (see Figure 34) lining the outside edge of the backs of each board with a 100 mm strip of tin further increases the strength of the boards and the attachment of glues, however this at the cost of weight. Pinboard fabric and protective angle was glued to this. A 100 mm tin
A strip runs across the middle of the rear of large boards (1600 × 1200 mm) which provides more attachment points for Velcro. Unfortunately this new design results in a significant increase in the weight of the large boards, and does not prevent the pinboards from bowing at all. It does provide a better attachment surface for the angle, however.

![Diagram of pinboard and whiteboard design](image)

**Figure 34** New designs for pinboards and whiteboards that provide for extra strength and better attachment as well as a reduction in weight from the Coreflute boards

**R26:** Build whiteboards and pinboards with a 100 mm strip of tin around the edges on the backs of the boards, as well as one through the middle horizontally for large boards. Pinboard fabric, protective angle, and Velcro swatches can be glued and riveted to this.

The pinboard and whiteboard manufacturer's performance was mixed but good overall. Many of the boards delivered were dirty (they were not protected with any sort of cover) and on a pallet too small for them (resulting in significant and persistent bowing of the Coreflute boards). Tin strips were not correctly positioned and fabric began to pull away from the backs of boards due to poor gluing. However, the pinboard and whiteboard manufacturer's sales staff members were very helpful in developing designs and very willing to provide samples and fix any problems by remanufacture of boards (although timeliness has sometimes been an issue), however there were significant delays (months) with the delivery of safety information of the materials used. With more precise requirements, a higher standard of manufacture must be required in any tender document.
6.4 Wiring

Although there have been significant improvements in the wiring and cabling arrangements for the CAT over those for the Intense Collaboration Space, further improvements are certainly possible. Currently the number of cables running to each access panel is nine (one power, three audio, one network daisy-chained to the next access panel, one USB, and three video). Furthermore, the distribution board has 16 cables running from it (six for powering the access panels, three for the down-lights, three for the fluorescent lights, three for the motorised projection screens, and one for RS-232 control of the Clipsal C-Bus system) and five running to it (five 15A power cables for supplying power). Wieland products may be a useful resource to consider when constructing new CATs to reduce the number of cables passing in and out of the distribution board (thus making it possible to make the board smaller). Consulting large electrical companies will provide access to their knowledge of the domain, including products and techniques that may result in better, more efficient installations and purchases. Colin Campbell of Artisan Technical Services is known to provide this kind of service and expertise to the manager of the DSTO Edinburgh presentation environments (including the Scot Allison theatrette and conference room).

R27: Consult with experts in electrical equipment when developing new CATs to simplify cabling and reduce the size of the distribution board.

Several Livespaces in operational environments have been set up using equipment that forwards data over the network, known as IP-based devices, rather than locating the devices where they are used, or using CAT5 cabling for extension. This allows the greatest scalability because the only cabling required to extend into a Livespace itself is one network cable (with the computers and other devices safely and quietly stored away from the workspace). Care must be taken not to overload the network, of course, but this kind of solution is far more scalable than the use of CAT5 cables or VGA and other data-specific cables. This scalability comes at a cost, of course, and devices that extend keyboard/video/mouse/audio/USB/Serial over IP are expensive. The benefits include not only less cabling but also locating computer equipment in more suitable environments such as server rooms. This allows for loud slim-line computers to be used instead of small desk workstations, and also means that the workspace is free from noise as well as clutter, allowing for speech-related technologies to work better (in addition to creating more comfortable work environments).

In a deployed environment, externalising computer equipment requires much more consideration. If the frame is situated in a tent, then the server “room” might also be a tent, which for reasons of communications and power cable length, and shared physical security, should be nearby. In an environment such as a ship, there may be more flexibility, relying on the ship’s infrastructure.

R28: Consider using IP-based extension devices to locate hardware in server rooms or other remote environments to rationalise cabling requirements and create more scalable comfortable workspaces.
One very important part of cable management is the labelling of cables. Using adhesive tape around cables for labelling presents problems as the adhesive wears and the labels slide around as it creates a sticky mess. Non-adhesive cable labels from business supply stores will avoid this kind of issue.

**R29:** Use off-the-shelf non-adhesive cable tags to label both ends of cables and avoid using adhesive tape for this purpose.

### 6.5 Distribution board

As mentioned in the previous section, by rationalising the number of cables needing to enter and exit the distribution board it can be modified in size and therefore weight making it easier to manipulate. The distribution board is 1200 × 600 mm and made of steel, making it extremely heavy, even when empty. Now that it has been fitted out, it will require special care to remove, should the CAT ever be re-located. Rather than relying on a commercial product, SES should be engaged to produce a lighter, smaller aluminium board with more appropriate attachment mechanisms.

**R30:** Engage SES to build a custom distribution board according to requirements from aluminium to reduce its size and weight.

![Figure 35](image)  
*A better mounting system for the distribution board. Thick aluminium angle is bolted to the back of the distribution board. The angle is then rested on and bolted to the corresponding frame beams.*

A better attachment mechanism consists of two large pieces of angle attached to the back of the board. These pieces of angle then rest on and are bolted to the Octanorm frame (see Figure 35).

**R31:** Use a more modular mechanism for attaching the board to the Octanorm frame, such as with large pieces of angle interfacing horizontally between the back of the board and the Octanorm cross-pieces.
The Clipsal C-Bus system, although excellent for our purposes, was over-equipped for our needs. In retrospect, a smaller number of relay and dimmer devices could have been purchased because the lights installed were installed as banks of lights instead of as individuals. Not only would a smaller C-Bus system suffice for our requirements, but it would also reduce costs, as the equipment is not inexpensive.

**R32:** Consider the Clipsal C-Bus system when developing the device control architecture.

Although not requested, a small wall switch panel was installed to control a number of the devices by C-Bus. While a software-based controller is not available, it is very useful to have this switch panel to control the devices.

**R33:** Include a small wall switch panel in requirements for a new room control system (Clipsal C-Bus or otherwise).

The 10A relays for the motorised projection screens failed (fused) and needed to be replaced twice, finally with 20A relays. It is suspected that this is because of the spike of amperage required when the motor starts up. A soft-start switch should be considered if problems persist. ScreenTechnics CD4 devices were not apparently required to interface between the C-Bus system and the projection screen motors, although in retrospect it is possible that these were designed to provide the protection the circuits required.

**R34:** Use soft-start switches to interface with the projection screen motor to avoid short circuits.

**R35:** If using a Clipsal C-Bus system with ScreenTechnics motorised projection screens, no CD4 devices are required to interface between the two.

The three-pin and four-pin plugs used on the power cables to connect the lights and projection screen motors are very easy to use and should be considered in the future, although plugs with lower profiles could reduce depth requirements.

**R36:** Use three-pin and four-pin plugs on the cables connecting the Clipsal C-Bus system with the room devices, if circumstances permit it.

Furthermore, a PC-Interface component that uses Ethernet rather than RS-232 is more flexible for programmatic control because the controlling program can run on any computer on the same network rather than needing to run on a computer directly connected to the component.

**R37:** Use an Ethernet-based PC-Interface component rather than a RS-232 PC-Interface component.

### 6.6 Access panels

The current design of the access panels provides network access points for more devices than it has the power capacity to support. Each access panel is powered by a 10A power cable and has eight power-points on it (two on the back and six on the front). This power also supplies
the internal 16-port network switch and the USB-over-CAT5 extension device. It is possible that if the number of network (and other data) ports is appropriate according to requirements then 15A or more of power should be supplied, otherwise the number of data ports could be reduced. Furthermore, by restricting access panels to support only required devices rather than catering for extreme flexibility, cabling requirements can be further reduced. With regard to network ports, rather than embedding a network switch and providing independent ports on the face of the panels, a rack-mount switch could be mounted to face directly out of the panel. As mentioned above, over-IP extension devices may reduce future requirements for cabling quite dramatically.

**R38:** Redesign access panels according to well-specified requirements to avoid unnecessarily over-developing them.

Regardless of specific requirements, the ports on the existing panels need better labelling and the layout should be modified if new ones are constructed. There is scope for making the panels slightly deeper, and more space can make initial wiring and maintenance easier. Also, because the types of devices may change over time, through-space and blank panels should be provided, which can be used when new types of cables must be forwarded through the panels.

**R39:** Ensure labelling and layout of ports on future panels is appropriate.  
**R40:** Make the access panels slightly deeper to aid fit-out and maintenance.  
**R41:** Provide blank ports on the access panels for unforeseen cabling requirements.

The procedure of manufacture was complicated but successful. The procedure consisted of the electrical and data cabling contractor developing a rough prototype to show how much space was required for fitting in the required devices and ports (both power and data) according to the schematics provided by research staff. This prototype was given to SES, which constructed another prototype to review with the electrical and data cabling contractor and research staff. Upon approval, this prototype was developed into the finished product. This entailed specifying the fabrication process from sheet metal (designs including cut and fold lines and attachment points) and painting the panels. The electrical and data cabling contractor recommended that future boards be painted before screwing them together, otherwise the screw heads become filled in with paint.

**R42:** Modify the original access panel schematics (in Figure 16 and Figure 17) according to requirements - they are sufficient for recreating the access panels.  
**R43:** Paint the access panel components before combining them with screws to prevent difficulty with taking them apart for fitting out with electrical equipment.

Although the access panel requirements stated that a circuit breaker be installed on each board, they were only installed in the distribution board. The issue was not pursued in this circumstance because it was deemed too minor to be worth the effort, but the requirements should stand for new access panels. Coupled with an ammeter, the circuit breaker makes the access panel an entirely independent device. Any failure on its local power network can be localised and power use can be monitored locally. This provides the ability to power the
panels with ordinary power cables from wall power-points without risking the circuit of those power-points.

R44: Each access panel should have its own circuit breaker and ammeter.

For security inspection purposes it may be necessary to use Perspex as housing for the access panels instead of painted sheet metal. The components we used generate little heat so there should be minimal fire danger from using a Perspex access panel.

R45: Use Perspex as access panel housing if greater visibility is required for security.

Make sure that network administrators are briefed on any devices that will connect to official networks (e.g. embedded network switches) and be prepared to alter designs to fulfil their operating requirements as well as security requirements. If possible, ensure access panels can be modified after construction in case security and IT infrastructure management rules and policies change.

R46: Get approval from local IT infrastructure administrators on access panel design prior to construction.
R47: Design with post-construction modification in mind to take into account changes in IT infrastructure policy and security rules.

Although the access panels are supported from beneath by a horizontal Octanorm beam, a method of ensuring they did not move horizontally out from the 'walls' needed to be developed, otherwise any time someone pulled a plug out of a board it could fall out. SES developed low-profile clips that attach to the side of the panels, behind the fascia to be unobtrusive (see Figure 19). These clips provide sufficient support that the panels will not fall out of the 'wells' spontaneously. To pull on a plug, however, still requires the person to hold the panel in place, otherwise the whole pinboard could be pulled away from the frame. This is obvious, however, and common sense or minimal training can be relied on to avoid this outcome.

R48: Reuse the clips designed by SES where appropriate or consider options available from Octanorm.

For mounting the ceiling panel, an alternative mechanism was required. After significant deliberation it was decided to provide horizontal struts attached to the underside of the Octanorm beams on which the access panel lies and to which it is bolted (see Figure 20). To allow for strength the struts were made from pieces of thick aluminium angle. To allow for variation in the distance between ceiling beams, one side of the angle had 100 mm slots cut in it, through which bolts could pass. For better aesthetics the struts could be cut to length or mounted on top of the frame. This is a functional and pragmatic solution and should be reused if possible.

R49: Reuse the ceiling mounting mechanism of thick slotted aluminium angle designed by SES for moderately heavy ceiling equipment.
6.7 Cable channels

To ensure cables are appropriately contained and neat a cable channel system was required. Given power cables should be separated from data cables to avoid electrical interference, it was decided to use two channels of 75 mm Oziduct. 100 mm channel would have been even more appropriate it turns out, due to how much cable we have, but 75 mm suffices. These channels sit alongside each other on top of 16 × 25 × 160 mm Octanorm extrusions that are attached at a uniform height to each column of the frame. The outer of the two channels is bolted to the extrusion to ensure the channels do not slide off. Although the Oziduct channel has a lid component, which clips on, we chose not to use it for ease of access (for maintenance as well as security). An alternative to purchasing Octanorm extrusions is to use the same tray-based mounting mechanism developed by SES for the lights to support the channel. It provides a tray and can be mounted on the horizontal inter-column beams. The advantage of the extrusions is that they can be attached at any height above ground level as they attach to the columns.

R50: Use Oziduct for the cable channels or any PVC-based open-channel alternative.
R51: Use Octanorm extrusions or SES-developed light mounting trays for supporting the channels according to specific requirements.

For supporting cables on parts of the frame where cable channel is not appropriate (e.g. up columns or on top of the frame) it is possible to bolt strips of Velcro to the frame using the Octanorm bolts and wingnuts. By running the cables across this Velcro and then attaching the corresponding strip on top of them, it will hold the cables in place to a degree, taking the weight off the cables, so that they do not pull against attachments. Cable ties are another option for this, but they are not reusable (at least, not easily). They are quick and strong, however.

R52: Consider Velcro bolted to the frame to support cabling outside of the cable channels in a flexible manner (compared with using cable ties).

6.8 Lights

Down-lights and fluorescent lights were used in order to mimic the lighting of a typical office collaboration environment. Due to the proximity of the down-lights to the ceiling of the frame there was concern that heat generated by the bulbs might cause a risk of fire, especially if the frame were housed in a tent. For this reason LED down-lights were experimented with. We used five Watt LED down-lights with a 20° beam and we found that the light they projected was unacceptably dim and blue in shade and unusable for a typical office/meeting environment. We therefore reverted to using standard halogen/dichroic bulbs, which generate a great deal more heat, but also more light. Furthermore, if the light mounts are attached so that the bulbs lie flush with the bottom of the Octanorm ceiling beams, there is sufficient space between the lights and the top of the frame to allow sufficient air flow to disperse any heat generated by the bulbs. There are now off-the-shelf protective caps available for downlights that may be considered.
The fluorescent lights were acceptable for our purposes.

**R53:** When selecting down-lights, constructors of CATs should be aware the LED down-lights generate a very different kind of light to standard down-lights, in terms of its colour and strength. Ensure that the down-lights chosen will fulfil the requirements of the users of the workspace.

### 6.9 Light mounts

The mounting mechanism developed for the lights underwent a number of revisions to arrive at the final solution. This involved SES prototyping and interaction with research staff and has delivered an excellent product for our requirements. In essence it is a tray which clips into horizontal slots in Octanorm beams (see Figure 27 for examples), but configurable enough to support a wide array of devices. Thick sheet metal can be used for heavy devices and holes can be cut and shaped as required (e.g. for down-lights or for recessing nuts and bolts).

**R54:** Reuse the SES-designed tray-based mounting mechanism for lights and other small to medium sized devices.

### 6.10 Projection screen mounts

The mounts designed by SES for the projection screens are appropriate for hanging a variety of heavy equipment off the Octanorm ceiling beams. Because the component interfacing to the Octanorm beam is thick and held by four M8 T-bolts, its strength easily supports any equipment hanging directly beneath it. These mounts can support heavy items which must be hung directly below ceiling beams.

**R55:** Reuse projection screen mounts where heavy equipment must be hung directly below ceiling beams.

### 6.11 Projector brackets

The projector brackets used were ScreenTechnics ‘spider’ brackets (Figure 25.a), consisting of three adjustable arms, which interface to the top of the projector, mounted on a detachable ball joint; this in turn attaches to the ceiling mounting plate. SES designed components for interfacing between the spider mounts and the Octanorm beams (Figure 25.b), which provide excellent support for very heavy devices hung directly below ceiling beams but where both sides of the beam are accessible. Although the spider mounts are simple and very flexible, it is possible that any provisional alignment achieved might be lost as part of the tightening of the ball joint due to twisting. There may be alternative projector brackets that provide flexibility while providing the ability for fine adjustment.

**R56:** Use SES-designed projector mounts where heavy equipment needs to be hung from ceiling beams and both sides of the beam are accessible (i.e. awkward at edge of frame).
6.12 Construction Practices

Due to the simple nature of the Octanorm fastening equipment, there were no particular lessons learned during the construction of the frame alone. Each component of the CAT was installed separately (i.e. the Octanorm frame was erected, the struts were attached, the pinboards and whiteboards were mounted, the projection screens were installed, and then the wiring and lights were installed). Some modifications of components (e.g. adding angle to some of the struts) may lead to a slight overlapping of some of the phases (e.g. mount lower pinboards, affix the next row of struts to ensure the angle lines up correctly, then mount the whiteboards), but it will be straightforward and obvious to use this order.

6.13 Tools

Now that the entire CAT has been constructed, it is apparent that not many tools would be required to rebuild it (assuming that components such as the distribution board and access panels have already been fitted out). The use of wingnuts allows hand tightening and further torque can be provided with a shifter wrench. Other than the Octanorm components which make use of an Allen key tool (unless using the Secure Tension Lock system, as recommended), everything is pluggable. Some specialised Allen key tools may need to be procured if constructing the CAT with little ceiling clearance.

6.14 Interaction and project management

Due to the custom nature of this project it was not possible to simply procure and integrate off-the-shelf hardware without expert knowledge and qualification (e.g. an electrician's licence). We engaged SES for designing, procuring and erecting the Octanorm frame and for designing and supplying the access panels and the mounting mechanisms. We engaged a data communications contractor (who subcontracted to an electrical contractor for the electrical component of the work) to provide the power and data capability from a central distribution board, including a Clipsal C-Bus system for controlling lights and motorised projection screens. The whiteboard and pinboard system was sufficiently customised to require detailed interaction with the pinboard and whiteboard manufacturer. In retrospect these three interactions highlighted the difficulty of relying on outside expertise in a research situation. Detailed requirements could not be stated at the start of the interaction, so extensive communication was required to develop a common understanding between all parties, and the delays caused by this must be understood and remembered for similar situations in the future.
When dealing with contracted assistance (whether it is SES or vendors outside DSTO), make it clear up front whether the work requires the strict fulfilment of exact requirements or if it is expected that the vendor will provide support and advice to develop requirements (relying on their expertise in the domain).

As researchers we hoped to rely on the expertise of the electrical and data cabling contractor for advice on improving our proposals for the distribution board and access panel designs. We assumed that the contractor would suggest improvements in the design (e.g. using Wieland components to reduce cabling requirements) with their knowledge of electrical components. Instead we were provided with, to the greater extent, exactly what we asked for regardless of the inefficiency of the design. The electrical and data cabling contractor treated our interaction as a strict requirements fulfilment task as opposed to an exploratory task and this is quite understandable as it had not been included in our requirements. In future DSTO researchers need to be clearer in specifying not only technical requirements but overall nature-of-project requirements also.

In contrast, when dealing with the pinboard and whiteboard manufacturer the representatives were very open to ideas and suggested improvements immediately (such as using the paper foam substrate, which had only just become available to them in the three weeks preceding our first meeting). This is highly likely due to the fact that they were also in a position of wanting to experiment with their new materials. As such they provided many samples and were very flexible with changes in requirements as new information came to light, including a willingness to take pinboards and whiteboards back to the factory to modify them. As mentioned already, high-level nature-of-project characteristics (such as high flexibility combined with low precision or high precision combined with low flexibility) should be included as selection criteria on tenders for similar exploratory work in the future.

Interaction with SES can be a mix of both exploratory work and strict requirements fulfilment, but it is necessary to be aware of which mode is being used at which points in the interaction. SES will experiment with designs and build prototypes to help develop requirements, but on the proviso that the prototypes are regarded as concept demonstrators and not finished products. Alternatively, if strict requirements are set and a well understood design is being used, then a high-quality finished product can be expected to be developed.

It is worth mentioning here again the unique situation of the construction of the access panels. Research staff developed a rough idea of what was required and how the access panels should look (internally as well as externally, see Figure 16 and Figure 17). The electrical and data cabling contractor prepared a preliminary prototype of the panel housing according to the size and shape of the components that would need to go into it. SES fabricated panels based on this rough prototype. The electrical and data cabling contractor then fitted out the access panels, including with equipment provided by research staff (USB extender and network switch devices). Despite all these interactions the production process went relatively smoothly but, as to be expected with multi-tasking of contractors, some stages took longer than others. If in future, however, the length of some of the stages starts to extend beyond what is reasonable, it is necessary to ensure that measures are in place to deal with them. These measures need to be included in contracts so they are enforceable. In this circumstance such measures were not included in our overall agreement with a vendor, to our detriment. In this
circumstance the electrical and data cabling contractor was hired using simple procurement and the contract used had no penalty clauses or an official due date (the default delivery date for simple procurement had been used and was unrealistic). A due date had been verbally agreed upon but was not met for a variety of reasons, many of which were outside the control of DSTO and the electrical and data cabling contractor. DSTO staff had contacted the DSTO Contracting Office for support in carrying the process out as a complex procurement prior to engaging the contractor but the request had been refused on the basis that the work was sufficiently simple to only warrant simple procurement. In retrospect, the Contracting Office should have been pressed for support to develop the contract to include means of redress when due dates were not met.

In short it is important that arrangements (including contracts) be more formal, and that goals and penalties be documented and agreed upon. This documentation can also be used to align expectations of requirements between the researcher and the vendor to avoid misunderstandings. These procedures are in accordance with the principles outlined in the Defence Procurement Policy Manual5.

R61: Make sure to get Contracting Office support for developing all contracts, especially when components of the contract rely on other parties.
R62: Use the Contracting Office support in preparing and distributing tenders to a broader range of potential vendors than the researchers may be aware of.
R63: Develop documentation detailing goals and penalties.

It should be noted that if resources are sufficient it is possible to arrange for SES to provide project management support as well as technical support.

R64: Consider using SES for project management support in circumstances where requirements can be expressed in detail (i.e. the work is not exploratory) at the start of the project.

With respect to project management, it is very useful for one single contact person to have the power to make decisions (or have easy access to someone who does), who is autonomous but guided by senior research staff. Having a diary, updated daily, of events and interactions regarding the project is a valuable resource. Whenever one person needs to hand that role over to another for a period of time (e.g. because they are taking leave) that diary can be maintained and kept up to date and the original person can be briefed by the temporary replacement upon their return. This avoids any confusion when requirements change during the period of absence, especially with regard to products ordered from vendors.

R65: Have a single person as the point of contact, empowered to make decisions, guided by senior researchers but able to act independently and autonomously.
R66: Maintain a diary of events and interactions, which is updated daily by whoever is fulfilling the role of project manager during the period of construction.

5 http://www.defence.gov.au/dmo(gc)/dppm.cfm
7. Conclusion

This report has provided an overview of the use of different types of frame for various Livespace instantiations, described the latest CAT in detail, and expounded the lessons learned during its construction and also provided recommendations based on those lessons. The motivation for this report is the growing popularity of the Livespace concept with DSTO's clients and especially the appeal of the CAT concept as a way of obtaining a Livespace capability rapidly and without major facilities work. If more CATs are to be developed it is important to improve the decision-making approaches to develop high quality products and form a basis for experimentation with new techniques and technologies.

The main recommendations that this report provides relate to three main areas:

- the design of components and sub-systems and how they integrate to produce a CAT,
- the importance of designing to the requirements of the target user and the difficulties arising from over-specifying, and
- the importance of clear communication with hired help, whether that be internal to DSTO (as with SES) or external, especially with regard to expectations of services provided and products developed at the project level as well at the component level.

Many of the findings and recommendations to be found in this report might be regarded as common sense, prudent project management and procurement practice, and good design. However, it is only through having experimented with the alternatives that it becomes obvious just how much better some options are. This experimentation will allow time and resources to be saved in similar future efforts. New requirements in different domains for different clients will provide new and perhaps competing requirements, which will require effort for redesigning some of the components and determining whether others require removal or addition.

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References


Appendix A: Summary of Recommendations

R1: Consider Octanorm as a frame vendor when frame system requirements include high frequency of assembly and disassembly.

R2: Tenders for exploratory projects in the future should include selection criteria for flexibility in working with changing requirements.

R3: Design the frame in detail and use Secure Tension Locks, or similar technologies, where possible and the more flexible floating (typical tension lock) mechanism only where such flexibility is required.

R4: Design the frame according to the requirements of the users, to avoid over-specification and extra cost.

R5: Obtain a laser line tool for ensuring the frame is square.

R6: Add a locking mechanism to the column foot adjusters during the design and quoting phase.

R7: Construct the frame in a space at least 1500 mm wider and deeper than the frame, and with 200 mm space above the frame.

R8: Ensure a beam other than the ceiling beam is used to maintain structural integrity in 'doorways' in the Octanorm frame.

R9: Use thinner, narrower Octanorm beams if weight is an issue, recognising that the thinner beams will not be able to support as much weight.

R10: Split long Octanorm beams if size an issue as long as the reduction in frame strength is accounted for.

R11: Use wingnuts wherever possible (and appropriate) instead of normal nuts.

R12: Consider using a zigzagged slot design with the strut flanges.

R13: Use a strut with an extended lip or one with a relieved flange to minimise the distance between the lower pinboard and the floor.

R14: Increase the width of the struts to 150 mm.

R15: Consider bolting pieces of angle to the struts to provide vertical support to the attached pinboards and whiteboards, rather than relying on the Velcro swatches, especially for heavy and large boards.

R16: Consider using an orthogonal arrangement of Velcro to ensure flexibility of attachment and maximum adherence of the Velcro glue.

R17: Rivet Velcro to the boards and wrap the corresponding Velcro all the way around the horizontal struts for the best attachment.

R18: Use Coreflute as the substrate for the large whiteboards and large pinboards, and use paper foam for the small pinboards, if using those materials.

R19: Increase the thickness of the sheet metal used for the struts to 1.5 mm for increased strength.

R20: During the design process, consider environmental effects on the CAT components, especially Velcro, glue and pinboard fabrics.

R21: Use paper foam substrate for small (1600 × 770 mm) pinboards and Coreflute for large (1600 × 1200 mm) pinboards and whiteboards.

R22: Wrap pinboard fabric around pinboard edges by at least 100 mm.

R23: Use Vertiface or RimTechnic pinboard fabric.

R24: Use the wrapped component of the pinboard fabric to attach to hook Velcro on the struts when mounting.
R25: Use 50 × 12 × 1.6 mm angle glued and riveted to the whiteboards to protect the edges.

R26: Build whiteboards and pinboards with a 100 mm strip of tin around the edges on the backs of the boards, as well as one through the middle horizontally for large boards. Pinboard fabric, protective angle, and Velcro swatches can be glued and riveted to this.

R27: Consult with experts in electrical equipment when developing new CATs to simplify cabling and reduce the size of the distribution board.

R28: Consider using IP-based extension devices to locate hardware in server rooms or other remote environments to rationalise cabling requirements and create more scalable comfortable workspaces.

R29: Use off-the-shelf non-adhesive cable tags to label both ends of cables and avoid using adhesive tape for this purpose.

R30: Engage SES to build a custom distribution board according to requirements from aluminium to reduce its size and weight.

R31: Use a more modular mechanism for attaching the board to the Octanorm frame, such as with large pieces of angle interfacing horizontally between the back of the board and the Octanorm cross-pieces.

R32: Consider the Clipsal C-Bus system when developing the device control architecture.

R33: Include a small wall switch panel in requirements for a new room control system (Clipsal C-Bus or otherwise).

R34: Use soft-start switches to interface with the projection screen motor to avoid short circuits.

R35: If using a Clipsal C-Bus system with ScreenTechnics motorised projection screens, no CD4 devices are required to interface between the two.

R36: Use three-pin and four-pin plugs on the cables connecting the Clipsal C-Bus system with the room devices, if circumstances permit it.

R37: Engage SES to build a custom distribution board according to requirements from aluminium to reduce its size and weight.

R38: Redesign access panels according to well-specified requirements to avoid unnecessarily over-developing them.

R39: Ensure labelling and layout of ports on future panels is appropriate.

R40: Make the access panels slightly deeper to aid fit-out and maintenance.

R41: Provide blank ports on the access panels for unforeseen cabling requirements.

R42: Modify the original access panel schematics (in Figure 16 and Figure 17) according to requirements - they are sufficient for recreating the access panels.

R43: Paint the access panel components before combining them with screws to prevent difficulty with taking them apart for fitting out with electrical equipment.

R44: Each access panel should have its own circuit breaker and ammeter.

R45: Use Perspex as access panel housing if greater visibility is required for security.

R46: Get approval from local IT infrastructure administrators on access panel design prior to construction.

R47: Design with post-construction modification in mind to take into account changes in IT infrastructure policy and security rules.

R48: Reuse the clips designed by SES where appropriate or consider options available from Octanorm.

R49: Reuse the ceiling mounting mechanism of thick slotted aluminium angle designed by SES for moderately heavy ceiling equipment.
R50: Use Oziduct for the cable channels or any PVC-based open-channel alternative.
R51: Use Octanorm extrusions or SES-developed light mounting trays for supporting the channels according to specific requirements.
R52: Consider Velcro bolted to the frame to support cabling outside of the cable channels in a flexible manner (compared with using cable ties).
R53: When selecting down-lights, constructors of CATs should be aware the LED down-lights generate a very different kind of light to standard down-lights, in terms of its colour and strength. Ensure that the down-lights chosen will fulfil the requirements of the users of the workspace.
R54: Reuse the SES-designed tray-based mounting mechanism for lights and other small to medium sized devices.
R55: Reuse projection screen mounts where heavy equipment must be hung directly below ceiling beams.
R56: Use SES-designed projector mounts where heavy equipment needs to be hung from ceiling beams and both sides of the beam are accessible (i.e. awkward at edge of frame).
R57: Use ScreenTechnics spider mounts for projectors if appropriate, but do look for alternatives.
R58: Construction should be performed by at least two people for safety and more at the start of the frame construction phase.
R59: It may not be necessary to purchase power tools for constructing CATs.
R60: When dealing with contracted assistance (whether it is SES or vendors outside DSTO), make it clear up front whether the work requires the strict fulfilment of exact requirements or if it is expected that the vendor will provide support and advice to develop requirements (relying on their expertise in the domain).
R61: Make sure to get Contracting Office support for developing all contracts, especially when components of the contract rely on other parties.
R62: Use the Contracting Office support in preparing and distributing tenders to a broader range of potential vendors than the researchers may be aware of.
R63: Develop documentation detailing goals and penalties.
R64: Consider using SES for project management support in circumstances where requirements can be expressed in detail (i.e. the work is not exploratory) at the start of the project.
R65: Have a single person as the point of contact, empowered to make decisions, guided by senior researchers but able to act independently and autonomously.
R66: Maintain a diary of events and interactions, which is updated daily by whoever is fulfilling the role of project manager during the period of construction.
Appendix B: SES Drawings

This appendix contains a selection of 3D drawings of the CAT by SES. They are not complete and do not show the final design but are included to give an indication of the processes used to develop the CAT.

Figure 36  An internal view of a side wall of the CAT, fitted out with projection screens and early conceptual access panels

Figure 37  An aerial view of the CAT within the CCSL, fitted out with projectors and projection screens
Figure 38  An internal view within the CAT towards the end wall with the large projection screen ready for projection

Figure 39  An internal view within the CAT towards the end wall with the large projection screen rolled up
Figure 40 An isometric view of a $6 \times 3$ module frame

Figure 41 An aerial view of a $4 \times 4$ module frame
Figure 42  A side view of a $4 \times N$ module frame

Figure 43  An isometric view of a $4 \times 3$ module frame
Figure 44 An isometric view of a $4 \times 3$ module frame

Figure 45 An end on view of a $3 \times N$ module frame, from the entrance end
Figure 46  An isometric view of a $3 \times 3$ module frame

Figure 47  An isometric view of a $2 \times 3$ module frame
Figure 48  An internal view of a $5 \times N$ module frame, with pinboard and whiteboard wall cladding
Appendix C: Miscellaneous Photographs

This section contains photos of the LiveFrame and its various components during the frame’s construction. There is no particular order to these photographs – they are included simply for posterity.

C.1. Light mounting plates and other components

Figure 49  A light mounting plate
Figure 50  Four different variations of light mounting plates
Figure 51  SES staff attaching a mounting plate to a fluorescent light
Figure 52  The fluorescent light fitted with a mounting plate
Figure 53 Attaching the fluorescent light to the frame by the mounting plates

Figure 54 A close-up view of how the mounting plates allow the light to hang from the frame

Figure 55 A fluorescent light and a downlight attached to the frame by mounting plates

Figure 56 Slotted angle brackets for mounting an access panel to the underside of the ceiling beams of the frame. The slots allow for devices with a variety of sizes.
C.2. Horizontal struts

Figure 59 A horizontal strut viewed from the end on

Figure 60 A horizontal strut in place, attached to an Octonorm column with T-bolts and supporting a pinboard with Velcro (not shown in Figure 59)
Figure 61  A horizontal strut with a lower lip viewed from end on. The lower lip provides support to the bottom pinboards.

Figure 62  Horizontal struts with lower lips shown in place. The one on the right is shown supporting a pinboard.

Figure 63  Horizontal struts installed in the Octanorm frame, ready for pinboards and whiteboards to be attached.

Figure 64  Horizontal struts in place, ready to support pinboards and whiteboards.
C.3. Data and power supply

Figure 65  Horizontal struts shown supporting pinboards and whiteboards from outside the frame

Figure 66  Pinboards with holes ready for access panels

Figure 67  Access panels and other equipment during installation
Figure 68  An access panel in place

Figure 69  A closer view of an installed access panel

Figure 70  The distribution board during installation

Figure 71  A rear view of the installed access panels showing cable management
C.4. Around the room

Figure 72 The ceiling of the frame includes several surplus beams to support extra devices. These can be rearranged by loosening and then sliding them.

Figure 73 Several of the surplus ceiling beams are aligned to support projectors.

Figure 74 The left side of the frame is structurally complete, with pinboards, whiteboards and projection screens installed.

Figure 75 A view of the ceiling, entrance, and back wall of the frame.
Figure 76 The top pinboards must be installed before the projection screens as they fit closely together. Moving the top pinboards once the projection screens are in place is difficult.

Figure 77 A view of the entrance to the frame, once the back wall is completely furnished with pinboards and whiteboards.
This report describes a Composable Adaptive TeamSpace (CAT) used to provide enhanced distributed collaboration support in mobile and/or re-deployable defence environments, and the lessons learned during the exploratory design and development phases. Various components of the CAT are discussed in detail, in particular the frame system, the whiteboard and pinboard wall panels, and the design and construction of the access panels, which act as hubs for data and power around the CAT. Experiences working with third party service providers (both internal and external) are also presented. To take advantage of the experience of this exercise, more than sixty recommendations are made for consideration during the design and construction of new CATs.