

Recommended Layouts for the En Route Area Supervisor Work Space

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16. Abstract Over the past decade, the Supervisor Work Space (SWS) at Air Route Traffic Control Centers (ARTCCs) has evolved to include as many as eight computer-based systems and other legacy equipment, paper reference materials, and supplies. Researchers from the Federal Aviation Administration Human Factors (HF) Team surveyed supervisors regarding equipment usage, location, and placement issues. Supervisors from 20 ARTCCs responded. The supervisors reported using computer systems approximately 50% of the time during a typical shift. They noted that their work spaces were cluttered, that placement of some systems made it difficult to see monitors or to access input devices, and that it was difficult to maintain the equipment. The HF researchers identified two common SWS layouts: (a) one layout in which the supervisor was seated in the main aisle looking into the operations area and (b) an alternate layout in which the supervisor was seated inside the operations area. The researchers developed baseline virtual reality models of the SWS based on HF guidelines and satisfactory aspects of existing work spaces. A working group of operational supervisors reviewed the baseline models and developed recommended layouts for the exterior, interior, and centralized command models of the en route area SWS.					
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Executive Summary

The operational Supervisor Work Space (SWS¹) in Federal Aviation Administration (FAA) Air Route Traffic Control Centers (ARTCCs) contains as many as eight computer-based systems, in addition to other equipment, reference materials, and supplies. As facilities added new systems, they placed them in space that was available. This evolution has led to clutter in the SWS. The FAA plans to introduce two new systems, the En Route Automation Modernization (ERAM) system and the En Route Information Display System (ERIDS), into the SWS.

The FAA En Route and Oceanic Service tasked the FAA William J. Hughes Technical Center Human Factors (HF) Team - Atlantic City, ATO-P, to collect data on (a) the current SWS layout of the ARTCCs, (b) the current usage of computer systems, and (c) the current problems encountered with the configuration. They also tasked the HF Team to develop a limited number of standardized design options to integrate ERAM and ERIDS into the work space in a manner that optimally supports the supervisors in performing their daily tasks.

After reviewing available documentation and discussing the SWS and tasks with operational supervisors, the researchers prepared a survey to collect information (monitor sizes, location in the work area, equipment usage during a typical shift, and usage difficulties) about the computer systems in the SWS. The En Route Supervisors Committee distributed the surveys. We received completed surveys from 35 areas of specialization in 20 ARTCCs. The researchers also visited five of the facilities to observe supervisors interacting with the SWS. There were two common SWS layouts. In the most common layout, the supervisor's desk is perpendicular to the rows of equipment in the operations area and the supervisor is seated in the main aisle facing the operations area (Exterior layout). Typically, there are two equipment racks collocated with the desk. In the second layout, the supervisor is seated inside the operations area with his or her back to the operations area (Interior layout). The desk width is extended and there is at least one extended shelf above the desk. Typically, the supervisor uses the communications equipment at the controller workstation located adjacent to the desk. There were, however, a small number of alternative layouts (e.g., desk parallel to the equipment rows, split areas), but these were functionally equivalent to the Exterior layout.

The supervisors reported using the computer systems (either monitoring or interacting with them) approximately 50% of the time during a typical shift, although there were wide variations in the time estimates. They use some of the systems very frequently and others only rarely, if at all. Not all operations areas have all the systems in the immediate SWS (e.g., some are shared between areas) and, in many cases, multiple systems share a display monitor and input devices. With three exceptions, the responding supervisors complained (a) that their work spaces were cluttered with the systems and other equipment and materials and (b) that the placement of the systems made it difficult to read the displays, to access the input devices, and to maintain the equipment.

¹ Initially, we labeled and distributed the survey as the En Route Supervisor Workstation Survey. However, after reviewing the survey responses, we elected to refer to the En Route Supervisor Workstation as the *Supervisor Work Space* because it encompasses the entire operations area.

The researchers developed two standardized baseline virtual reality (VR) models: one model for the Exterior layout and one model for the Interior layout. We based the designs on HF guidelines and practices from facilities that had reported satisfactory layouts on the survey.

We convened a Working Group (WG) of representatives from FAA Headquarters and ARTCC facilities to review the VR models and to make changes based on operational considerations. The WG evaluated the baseline VR models and developed recommended configurations for the Exterior and Interior layouts. Although the group selected the Exterior model as the preferred configuration, they developed options for the Interior model for facilities that elected to retain that layout. The WG also generated a model of a Centralized supervisor work area that may facilitate transition to future air traffic control concepts.

1. INTRODUCTION

Air traffic controllers in Federal Aviation Administration (FAA) Air Route Traffic Control Centers (ARTCCs) maintain the separation and sequencing of aircraft transitioning to and from terminal areas and at high altitudes en route to their destination. The ARTCCs are divided into areas of specialization, usually containing six to eight radar sectors overseen by one or more operational supervisors.² The supervisors monitor the situation in the area, ensuring proper staffing for the number and complexity of aircraft being controlled and providing assistance when needed. The supervisors also have a work space where they perform other operational and administrative tasks. The en route area Supervisor Work Space (SWS³) has evolved over the past decade to include a number of computer systems with new information and tasks for the supervisor to perform. In most cases, each new system included a new monitor, associated computer processor units (CPUs), and input devices.

The current SWS may contain an administrative computer, a Traffic Situation Display (TSD), a system status display, a scheduling and sign-in/sign-out (SISO) system, one or more controller work tracking systems (called CRU-ART), a keyboard video display terminal (KVDT) to the radar and flight plan processing automation system, a weather display (usually the Weather and Radar Processor [WARP]), a Voice Switching and Control System (VSCS), and a Corridor Integrated Weather System (CIWS), which is a tactical tool that provides high update rate weather information on storm locations and echo tops. The SWS also typically contains telephones and other communications equipment, Read and Initial binders, and paper reference materials. There are substantial differences between ARTCC facilities with respect to the SWS. For example, not all facilities have all systems located at the SWS; sometimes systems share monitors and input devices, and sometimes the layout of the work space is determined locally. There are also differences in layout between areas within an ARTCC. In nearly all cases, however, the SWS is limited in size and cluttered with equipment, documents, filing cabinets, and other items.

The FAA plans to introduce two new systems into the SWS: the En Route Information Display System (ERIDS), which replaces most of the paper reference material, and the En Route Automation Modernization (ERAM) system, which replaces the legacy automation system. Although some materials will be removed eventually (e.g., the KVDT and paper references), these new systems will further complicate an already limited work space. Therefore, the FAA En Route and Oceanic Service tasked the FAA William J. Hughes Technical Center (WJHTC) Human Factors (HF) Team to collect data on the current ARTCC SWS layouts, the current usage of computer systems, and the current problems encountered with the configuration. In addition, they tasked the HF Team to identify guidelines and standards for the SWS layout and to use virtual reality (VR) modeling to support a supervisor's work group in developing a limited number of standardized layouts that will optimally support the supervisor's job performance.

² Operational supervisors were subsequently renamed Front Line Managers, but we retained the previous terminology.

³ Initially, we labeled and distributed the survey as the En Route Supervisor Workstation Survey. However, after reviewing the survey responses, we elected to refer to the En Route Supervisor Workstation as the *Supervisor Work Space* because it encompasses the entire operations area.

2. METHOD

The HF Team surveyed ARTCC supervisors to determine the current en route SWS equipment configuration and to gather estimates of their computer system usage. The researchers also visited five ARTCCs to observe the SWS layouts and to interview supervisors about their task performance using the systems in the SWS. Next, they developed recommendations for the placement of each system based on HF guidelines and the operational needs of users. Finally, the HF Team convened a WG meeting with representative users to evaluate the baseline layouts and to make changes to enhance usability and operational suitability. This section describes the methodology for each of these activities.

2.1 En Route Supervisor Survey

The purpose of the survey was to collect information regarding current en route SWS layouts, supervisor computer system usage, and work space concerns, such as identifying major problems with the layout of the supervisor areas and identifying any equipment that was difficult to monitor or access. The HF Team collaborated with a National En Route and Oceanic Supervisor Committee (SUPCOM) representative and a supervisor to prepare the survey.

The survey consisted of four primary sections (see Appendix A). In the first section, we asked the supervisors (a) to rate how frequently they use each of the computer systems, (b) to identify the size of the display for each system, (c) to identify any shared equipment or systems, and (d) to provide the width of the main aisle. In the second section of the survey, we asked the supervisors to draw an area floor plan that included the location of the controller Display System Replacement (DSR) workstations and the supervisors' desks, equipment racks, and tables that are part of the SWS. In the third section of the survey, we asked the supervisors to draw a sketch of the location of the CPUs, displays, and input devices for equipment on the supervisor's desk, equipment rack(s), and table(s). In the fourth section of the survey, we asked the supervisors (a) to describe the problems they experienced and (b) to provide recommended solutions to the problems. The SUPCOM representative conducted a pretest of the surveys with supervisors at his facility.

The National En Route and Oceanic SUPCOM representative e-mailed copies of the survey and an instruction sheet to the ARTCC facilities. We requested that operations supervisors complete the survey for each unique operations area within their facility. If the SWSs were slightly different, the respondent could simply note the differences on the survey. The respondents faxed the completed surveys, including photographs, if available, to the HF Team researchers. If facilities did not respond within the deadline, the SUPCOM representative sent a follow-up request.

2.2 Human Factors Guidelines

We reviewed HF standards and identified pertinent guidelines to be applied in developing the standardized layouts. The documents we reviewed were Ahlstrom and Longo (2003), Cardoso and Murphy (1995), Department of Defense (DOD, 1999), and Grandjean (1988).

2.3 Working Group Meeting

In preparation for the WG meeting, the HF Team researchers collaborated with the Lab Future Development Subteam at the WJHTC to develop standardized, three-dimensional VR models representing the two common supervisor work area configurations. We applied HF guidelines (Ahlstrom & Longo, 2003; DOD, 1999) in locating the equipment and selecting shelf heights when developing these baseline VR models.

The HF Team convened the WG meeting at the FAA WJHTC Research Development and Human Factors Laboratory on September 12-14, 2006. The WG included eight Air Traffic Control (ATC) Subject Matter Experts, six HF practitioners, and one ERAM systems engineer. The objective of the meeting was to review the two baseline VR models and to modify the SWS so that it supports the supervisors' tasks more effectively. The VR model enabled the WG to view the workstation from any location and to move equipment within the virtual space to evaluate configuration options. A secondary objective was to develop a new concept for a centralized supervisor work area.

3. RESULTS

In this section, we present results from the three activities performed in support of the project. We present results of the survey, relevant HF guidelines, and products from the WG meeting.

3.1 En Route Supervisor Survey

Twenty of the 21 ARTCCs responded to the survey, representing a response rate of 95.3%. The project sponsor provided photographs of the remaining center. Six facilities provided information on more than one area, resulting in data for 35 different areas. Three ARTCCs provided surveys on two areas, two ARTCCs provided surveys for four areas, and one ARTCC provided surveys for seven areas. We received digital photographs from 10 facilities.

3.1.1 Area Floor Plan

Each ARTCC has a main aisle with operational areas branching off perpendicular to the aisle. Eleven ARTCCs reported the most common main aisle width as 6 ft (1.8 m). None of the aisles were less than 6 ft (1.8 m), although in some facilities, furniture (e.g., coat racks, headset storage cabinets) occupied some of the width of the aisle. The widest aisle reported was 12 ft (3.7 m).

We determined the primary SWS orientation to the operations area for each facility (some had an exception) based on the survey drawings and digital photographs. There were two primary orientations, both of which had the supervisor's desk perpendicular to the area controller workstation rows. The facilities could align the desks on either the left or right row of controller workstations (see Figure 1). At 12 of the facilities, the supervisors are seated in the main aisle looking into the operations area (Exterior layout). Seven facilities reported that the supervisors sit in the operations area with their back to the operations area (Interior layout). In one facility, the desks were perpendicular with the supervisor sitting in the aisle, but the operations area included controller workstations on both sides of the aisle. Functionally, however, this layout was very similar to the Exterior layout. The final facility had the supervisor's desk parallel to the controller workstations; at least two other facilities had a similar arrangement in only one of its areas. The space available on the desk and equipment racks was also similar to the Exterior layout.

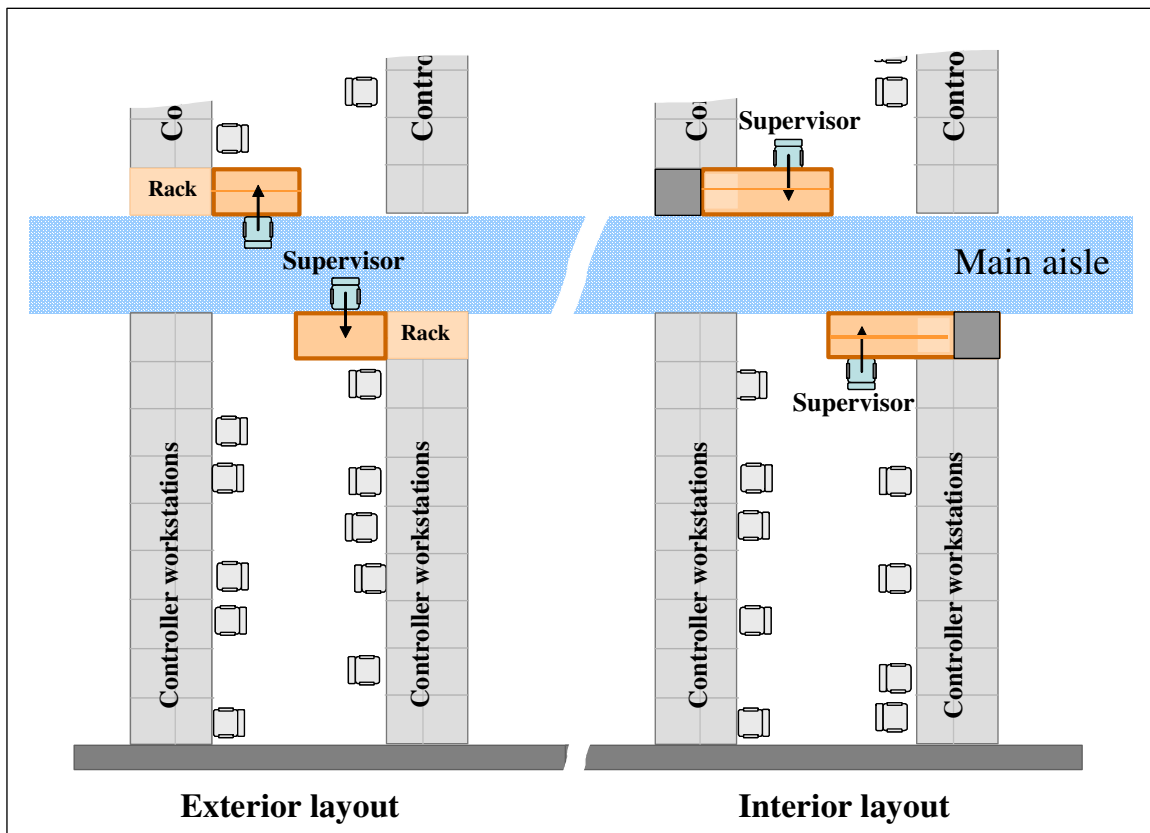


Figure 1. Common supervisor orientations to the operations area.

3.1.2 Supervisor Work Space

The Exterior layout for the SWS typically comprised a desk with a shelf above it and two equipment racks. Figure 2 is an example of a typical exterior supervisor workstation. Other variations were a single rack, three racks, or a rack and a table. The Interior SWS typically had an extended desk (8 ft or 2.44 m) and at least one shelf above the desk; these were functionally equivalent to a desk and an equipment rack. The supervisors could also use the controller workstation located immediately beside them. The height of the supervisors' desks ranged from 28 in. (71 cm) to 42 in. (107 cm). The most common desk height was 30 in. (76 cm). The width of the desk was approximately 5.5 ft (1.67 m). The racks ranged from 24 in. (61 cm) to 30 in. (76 cm) in width and were 84 in. (213 cm) in height. Supervisors could adjust the height of shelves in the racks. The desks and racks were approximately 30 in. (76 cm) in depth.

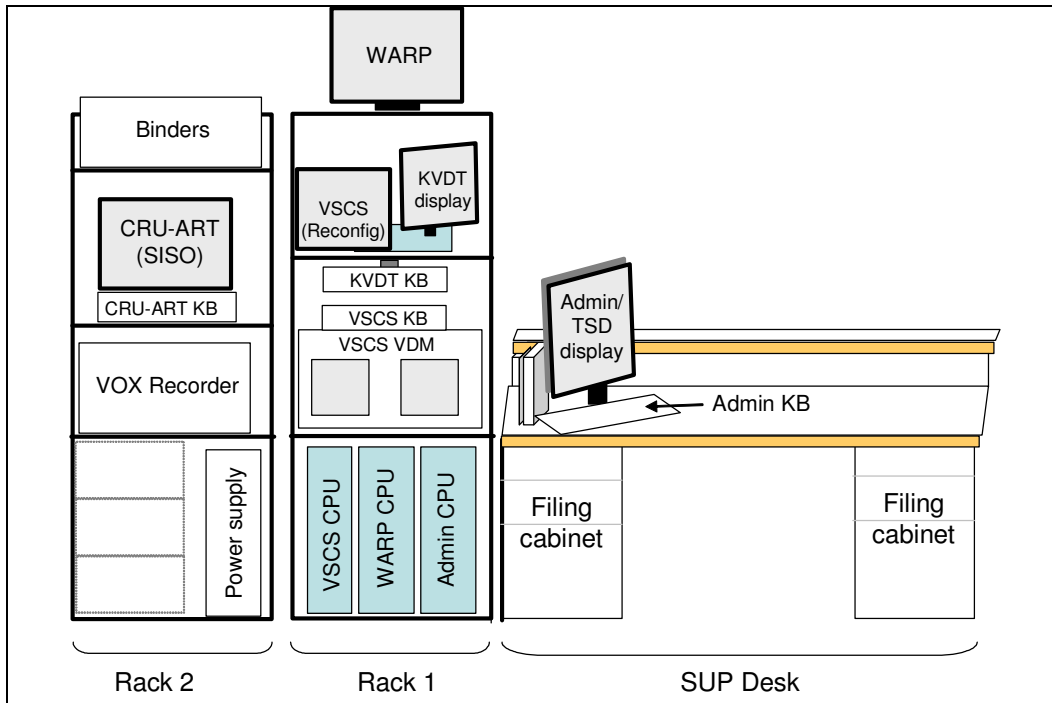


Figure 2. Representative exterior supervisor equipment layout.

The supervisor's desk typically included a large work surface supporting an administrative PC display, administrative input devices, reference materials, and at least one phone. Frequently, there was at least one additional computer monitor with input devices on the desk. Usually, there were one or two filing cabinets under the desk along with the administrative CPU. Some facilities used the shelf above the supervisor's desk for binders or other paper reference materials. Other facilities used this shelf for WARP, TSD, or the controller CRU-ART display.

The equipment racks were located on either the left side or right side of the supervisor desk, with the location typically alternating from one area to the next within a facility. The racks usually included at least three shelves and housed the VSCS Video Display Module (VDM), WARP, VSCS reconfiguration workstation, and controller CRU-ART. Figure 3 provides a labeled photograph of equipment racks and two representative examples of the SWS.

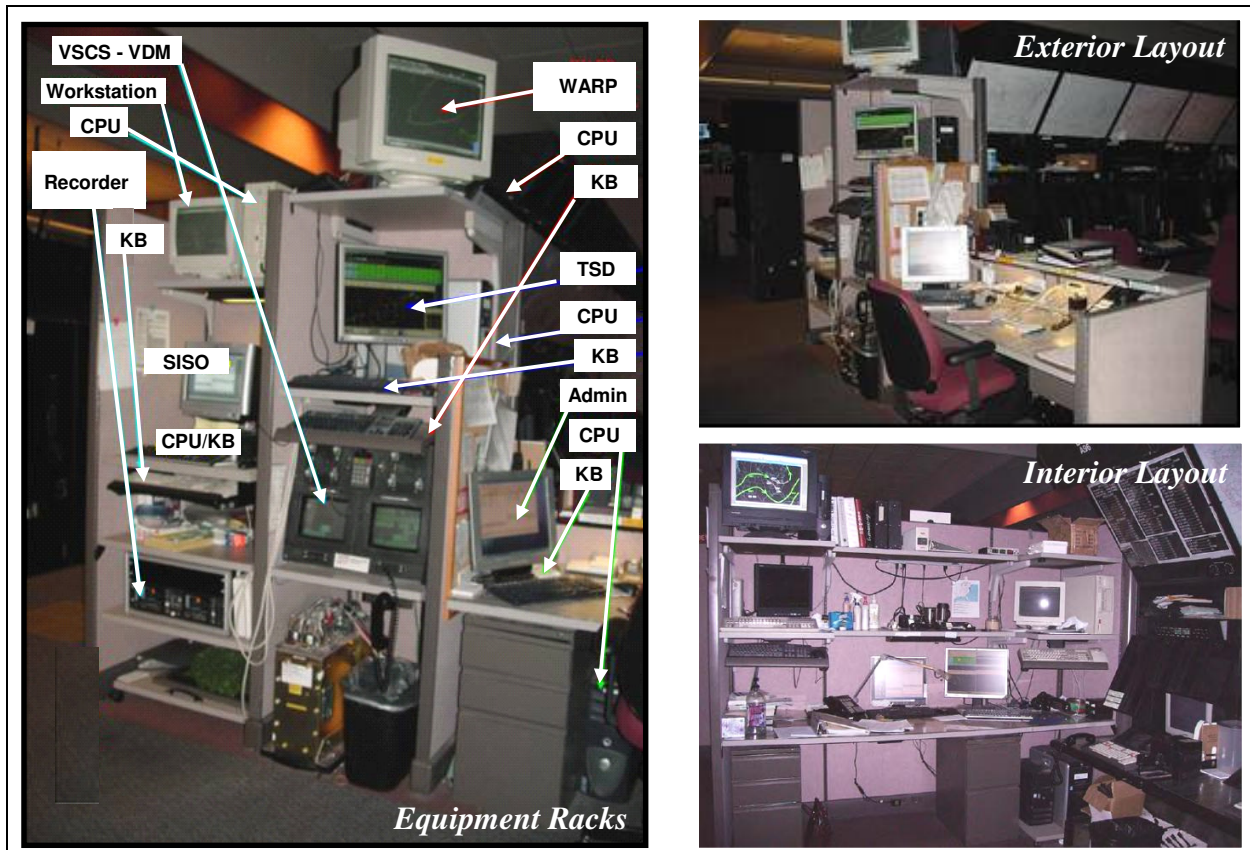


Figure 3. En route supervisor equipment racks and representative work spaces.

3.1.3 Equipment Location

Among the primary components for each system were a display and a CPU. Table 1 summarizes the location of these components. We did not include input devices (i.e., keyboard, mouse, or trackball) in the table because they require minimal space and are typically in close proximity to the system display. In addition, not all the respondents indicated the location of the input devices. Some respondents did not indicate the location of the CPUs, so we list many as unidentified.

There were substantial differences in the location of almost all equipment across facilities (see Appendix B). The only systems demonstrating significant commonality were the supervisor administrative display (which was always on the supervisor's desk) and the VSCS VDM. The VSCS VDM was most often in Rack 1 (for the Exterior layout) and in the controller workstation (for the Interior layout). At just over half of the reporting areas, supervisors shared the administrative display with at least one other system; most commonly, they shared it with the supervisor CRU-ART system (12 areas) or TSD (5 areas). Although the weather display was usually situated in Rack 1, many facilities placed it on the supervisor shelf facing the operations floor. Facilities placed the KVDT display in a variety of locations. Rack 1 most frequently held the VSCS VDM, VSCS reconfiguration, and CRU-ART displays. In addition, it was the most common location for all system CPUs, except for the KVDT CPU. The controller CRU-ART SISO computer was most often located in Rack 2. Nine facilities, representing 12 areas, indicated that an analog tape recorder was in the SWS, but the respondents indicated that they rarely, if ever, used it.

Table 1. Equipment Locations

Equipment		Supervisor desk	Shelf	Rack 1	Rack 2	Other Location	Total
Display	Administrative (Admin)	15					15
	Admin/CRU-ART	12					12
	Admin/CRU-ART/TSD	1					1
	Admin/ERIDS	1					1
	Admin/TSD	5					5
	Admin/TSD/CRU-ART/ERIDS	1					1
	Weather (WARP, Corridor Integrated Weather System [CIWS])		16	17		2 ^a	35
	VSCS (Reconfiguration)		6	14	6	1 ^a	27
	VSCS (VDM)		1	21	1	1 ^a	24
	TSD	10	5	8	1		24
	KVDT	3	7	4	3	4 ^a	21
	CRU-ART (SISO)		3	3	6	4 ^a	16
	CRU-ART (SUPE)	2	2	2	5	1 ^a	12
	TSD/(ESIS)	2		1			3
	Center-TRACON Terminal System	2					2
	Computer-Based Instruction					1 ^a	1
Total		54	40	70	22	14^a	200
CPU	Admin	4		18	1	5 ^b	28
	Weather (WARP, CIWS)		7	14	1	2 ^b	24
	CRU-ART	4		4	3	3 ^b	14
	ESIS			5			5
	KVDT	1	3	2	2	2 ^b	10
	TSD			14	3	1 ^b	18
	VSCS (VDM)		1	7	4		12
	VSCS (Reconfiguration)		1	6			7
	Unidentified system	1	1	22	3	8 ^b	35
	Total		10	13	92	17	21^b
Other	Uninterruptible Power Supply		1	6		4 ^b	11
	A/B switch	5	1	2		1 ^b	9
	Tape Player			5	7		12

^a Located in a separate rack in the operations area or in a rack that is shared with an adjacent area.

^b Located under the supervisor's desk.

The surveys identified the location of 161 CPUs, which included 153 CPUs in the SWS and 8 CPUs in other remote racks on the operations floor. More than half of the CPUs were located in Rack 1 (see Table 1). Of the CPUs in the SWS, most were in the bottom of a rack (72) or under the supervisor's desk (21). The remaining 68 CPUs were located in the middle of a rack (29), on a shelf (13), on the supervisor's desk (10), on top of the rack (8), or in an unspecified location (8). The eight CPUs located in an area away from the SWS included CRU-ART (3), Weather (2), KVDT (1), VSCS (1), and the computer-based training CPU (1).

3.1.4 Display Size

The respondents provided the diagonal display size for the systems available to them (see Table 2). The range for the CRU-ART display is especially large because it includes the supervisor CRU-ART functionality (which is often shared on the supervisor's administrative computer) and the standalone CRU-ART system that controllers use to sign in and sign out. The administrative computer displays were most commonly 17 in. (43.2 cm) but ranged from 15 in. (38.1 cm) to 20 in. (50.8 cm). The TSD and WARP were the largest displays, typically 20 in. (50.8 cm), but there was some variability in them as well. The VSCS displays represented a relatively large range because the SWS included two separate displays with different characteristics. One system, the VSCS VDM, which supports air-to-ground and ground-to-ground communications, typically comprised two small touch screen displays. Supervisors use the second system, the VSCS reconfiguration workstation, to reconfigure frequency assignments. This system consisted of a standalone supervisor workstation with a single display. The display for the VSCS reconfiguration workstation tended to be larger than the display for the VDM. Only three facilities had the ERIDS prototype. In one facility the ERIDS display was shared with the administrative display. In the remaining two facilities the ERIDS displays were 18 in. (45.7 cm) and 19 in. (48.3 cm).

Table 2. Approximate Diagonal Display Size

Equipment	Count	Mode	Range
CRU-ART	34	17	14 - 21
Administrative PC	35	17	15 - 20
TSD	35	20	15 - 21
WARP	35	20	17 - 24
KVDT	26	15	13 - 20
VSCS	27	15	8 - 24
ERIDS	2	18.5	18 - 19

3.1.5 System Usage

The responding supervisors estimated that they use their computer systems on average, during a typical shift, approximately 52% of the time, but this rating was highly variable ($n = 34$, $SD = 27.0\%$, Range = 10-100%). Usage included both monitoring the system for information (e.g., monitoring traffic flows and weather) and interacting with the systems (e.g., entering information in the administrative computer or CRU-ART). The respondents then rated the frequency of use for eight systems on a 5-point scale that ranged from 1 (*almost never*) to 5 (*very frequently*). The supervisors rated CRU-ART as the most frequently used system, followed by the administrative PC and TSD (see Table 3). Three ARTCCs had a prototype of the ERIDS available at the supervisor workstation, but they reported using it approximately 1 time per shift. Except for CRU-ART and ERIDS, there were many differences in usage between the areas.

Table 3. Supervisor Ratings: Frequency of System Use

Equipment	Description	Count	Mode	Range
CRU-ART	Areas typically include separate supervisor and controller systems. Supervisors use the system to manage staff schedules, time on position, and other staffing functions.	33	5	3 - 5
Administrative PC	General supervisor administrative functions, including daily log and word processing.	34	4	2 - 5
TSD	Graphically displays current aircraft positions. Used to monitor the position of air traffic and traffic demand on airports and sectors.	33	4	1 - 5
WARP	Displays weather data.	33	3	1 - 5
KVDT	Provides access to general information messages and advisory messages from Host.	26	2	1 - 5
VSCS	Includes two different systems. One system permits supervisors to reconfigure frequencies at workstations. The other system provides air-to-ground and ground-to-ground voice switching control system.	32	1	1 - 5
ERIDS	A prototype system that provides real-time access to ATC documents, traffic management data, and other information.	3	1	1 - 1
A/B Switch	Used to switch between multiple computer systems for a single display and input devices.	12	1	1 - 5

3.1.6 Current Work Space Issues⁴

On the survey, we requested that the responding supervisors identify major problems with the layout of the current SWS and report any issues related to the access or monitoring of computer systems. The respondents had different comments for the two common floor plans. In areas where the supervisors are seated in the main aisle, they can restrict the movement of people or equipment along the aisle, particularly at facilities that have a 6 ft (1.8 m)-wide aisle. They also reported that, occasionally, heavy traffic volume behind them negatively affected their ability to monitor operations. Another limitation of this orientation is that computer monitors can block their view of the operations area. Supervisors at facilities employing the Interior layout reported that being oriented with their back to the operations area reduces their ability to monitor the operations floor. Locating supervisors in the area often results in the loss of a controller workstation, which may be unacceptable at many facilities.

The primary problems with the layout of the SWSs included limited desk or work space, difficulty accessing input devices, difficulty identifying which input device or CPU was associated with which system, disorganized wiring, employees crowding around the supervisor's desk when using the SISO computer, and other comments related to unused equipment. Table 4 identifies the primary considerations and includes representative comments to elaborate on the nature of the issue.

⁴ In a separate but related project sponsored by ATO-E, an en route supervisor job task analysis (Human Solutions Inc, 2006) resulted in corroborating evidence about the current design and issues associated with the SWS.

Table 4. Current SWS Issues

Issue	Representative Comments
Limited desk or work space	<ul style="list-style-type: none"> • The major problem with all the equipment on the supervisor's desk is that it does not leave enough room for work space. • All of the systems take up too much space--desk and shelf areas are very congested. • Supervisor's workstation is very crowded with charts, paperwork, and stuff! Very difficult to get around. • Five different keyboards at the supervisor's desk add to clutter. • OS desk is cluttered with three phones, two keyboards, a clock, and an admin monitor. • The CPU for the controllers ART is under the desk and gets kicked quite often.
Difficult to access, use, or monitor some systems	<ul style="list-style-type: none"> • Admin keyboard located on desktop is too high and at poor angle--it is very uncomfortable for long-term use. • We don't need it often, but the VSCS keyboard is located behind and on the same shelf as the KVDT keyboard. • The communications computer (used to change VSCS maps) is difficult to access due to the location of the keyboard and mouse--the slide drawer sticks. • VSCS display is hidden below strip bays and requires SUP to duck below bottom edge of bays to see the display. • WARP computer is too high to use. • Weather display keyboard is difficult to use because of its location. • TSD mouse located on desktop too far from keyboard/knee space to reach comfortably. • Must stand up and reach to get to input device for TSD and weather display. • The keyboards are at several levels and when using several systems in a short time, you feel like a Jack-in-the-box. • CRU-ART/airspace monitor on admin display shared with TSD display. Difficult to monitor all tasks.
Difficult to tell which input devices go with which system	<ul style="list-style-type: none"> • So many keyboards and mice, we often get them confused and begin to use the wrong one. • It's sometimes confusing to track which mouse or keyboard goes to which monitor, with all the cables crossing over each other and A/B switches. • TSD display and input devices are separated by 3 feet.
Unlabeled CPUs	<ul style="list-style-type: none"> • All the equipment is in close reach, but the CPUs are not labeled for their particular function--most of the equipment is behind the sup desk. • Labeling the CPUs would help when the systems have failed and will not start up easily.
Disorganized wiring	<ul style="list-style-type: none"> • Lots of cable and cords at feet under desk (sometimes get disconnected). • It's sometimes confusing to match input devices and systems with all the cables crossing over each other and A/B switches.
Employee crowding around desk for SISO	<ul style="list-style-type: none"> • Employees crowd area around desk when manipulating CRU-ART. • CRU-ART input difficult for controllers to use when supervisor is at desk. • Sign in and sign out causes a lot of traffic at desk.
Difficult to access some systems for cleaning and maintenance	<ul style="list-style-type: none"> • The CPU is very high and difficult to reach when a reboot becomes necessary. • The CPUs for TSD and admin are very difficult to access for maintenance or repair. • The admin CPU and Corridor Integrated Weather System CPU are nearly inaccessible.
Other equipment issues	<ul style="list-style-type: none"> • Tape recorder is broken, not maintained, and obsolete. • A/B switch is not used anymore. That would free up some space. • Current VSCS does not allow for cordless phones. Any calls taken on VSCS force you away from sectors, as VSCS is too far away. You cannot talk on VSCS and observe sectors at the same time.

Although the surveys revealed several problems with the SWS, respondents at three facilities reported that their layouts were good. In general, these sites shared the following characteristics.

- The administrative computer monitor was on the supervisor's desk, and the system was shared with the CRU-ART system.
- The weather monitor and TSD were always available for monitoring.
- The VSCS VDM was close to the supervisor in a very accessible location (often on the middle shelf of Rack 1).
- The controller SISO station was at standing height away from the supervisor's desk.
- The CPUs were organized adjacent to other CPUs and were located at the bottom of a rack or under the supervisor's desk where it did not restrict leg space.

3.2 Human Factors Guidelines

One of the primary goals of this project was to provide recommendations for an optimal work space design. In support of this objective, we identified relevant HF principles for the optimal layout of equipment and working surfaces to support the supervisor's task. As with all user-centered designs, our goal was to fit the work space to the user, not the user to the work space (Cardosi & Murphy, 1995). We relied primarily on four sources of HF guidelines, two of which specifically addressed the design of ATC facilities. The references were *Human Factors Design Standard: HF-STD-001* (Ahlstrom & Longo, 2003); *Human Factors in the Design and Evaluation of Air Traffic Control Systems* (Cardosi & Murphy); *Design Criteria Standard - Human Engineering: MIL-STD-1472F* (DOD, 1999); and *Fitting the Task to the Man: A Textbook of Occupational Ergonomics* (Grandjean, 1988). The following list presents some of the relevant design principles for the current project.

- Lay out equipment to minimize traffic and congestion (HF-STD-001, 10.3.1.2).
- Place work surfaces for seated positions 29 in. to 31 in. (740-790 mm) above the floor (HF-STD-001, 10.2.7.2).
- For standing tasks requiring precision, the recommended height from the floor to the top of the workstation is 37.4 in. to 41.3 in. (95-105 cm) for women and 39.4 in. to 43.3 in. (100-110 cm) for men (Grandjean). Therefore, the optimum range supporting both populations is 39.4 in. to 41.3 in. (100-105 cm).
- Place systems that require more use (frequency or duration) in more accessible locations (Cardosi & Murphy, 9.2.2; HF-STD-001, 10.3.1.8).
- When locating workstation components, ensure the visibility of controls and displays, ensure that there is adequate clearance between controls, and ensure that users can reach controls without excessive shoulder movement or bending of the back (Cardosi & Murphy, 9.3.4).
- Locate the heaviest or bulkiest equipment at the most accessible locations (HF-STD-001, 4.3.4d).

- Locate all equipment and components to minimize the possibility of equipment damage, personnel injury, or inadvertent actuation (HF-STD-001, 10.3.1.6).
- Label all items that personnel must identify (HF-STD-001, 4.3.5.1.1; MIL-STD-1472F, 5.5.1.1).
- Arrange workstations to allow accessibility to system components for easy removal and replacement by maintainers and support technicians (Cardosi & Murphy, 9.3.2; HF-STD-001, 10.1.3).
- Ensure maintenance activities do not interfere with ongoing operator tasks (HF-STD-001, 10.1.5).

The HF Team researchers used these general HF principles to prepare the two baseline VR models. The following describes how we applied the design principles when locating the shelves and equipment.

- 1) Supervisors employ one of two common interaction styles when using computer systems at their area: monitoring or active. Their style of interaction holds implications for optimal display location.
 - a. **Monitoring.** Monitored systems should always be available to the supervisor, but they do not necessarily need to be located in close proximity to them. Examples of monitored systems include the TSD, ERIDS, WARP, and CIWS. An important consideration in our final layout for the Exterior configuration was the ability to provide TSD and ERIDS information to the supervisor whether they were at the supervisor desk or on the operations floor. We accomplished this by placing these displays above the desk and locating them on a pole that permits the display to swivel toward each location. Standards require placing monitored systems at heights where users can see them while seated or standing.
 - b. **Active.** Supervisors interact with a number of different systems using keyboards, mice, and trackballs. It is essential that frequently used systems be placed in close proximity to the supervisor in an easily accessible location. Users can only actively interact with one system at a time; therefore, it may be desirable for several of these types of systems to share a common display and input device. By sharing components, users can reclaim valuable desk space and can avoid other concerns, such as the confusion of identifying which input devices control which systems. Among the systems that we recommend share a display and input device are the administrative display and supervisor CRU-ART. The administrative monitor could display the VSCS reconfiguration if this would meet operational requirements. It may be possible to also share input devices for TSD and ERIDS, but these systems need a separate display. Facilities place the Enhanced Status Information System (ESIS) on the walls of the operations area, but it requires input devices at the SWS. We recommend sharing the displays and input devices by using a Keyboard, Video, and Mouse (KVM) switch. We recommend the purchase of an eight-way KVM switch to support current needs and to provide flexibility for future expansion. This switch must be highly reliable, be usable 7 days a week for 24 hours, and demonstrate good HF principles (ease of use, and so on.).

- 2) Facilities should situate systems with which supervisors interact most frequently as close as possible to the supervisor's seated desk location. Commonly used systems include the administrative PC, supervisor CRU-ART, and to a lesser degree, ESIS. Supervisors rarely use the VSCS reconfiguration display, therefore, we recommended that facilities locate it relatively far from the supervisor. We located systems that require relatively frequent monitoring in an easily viewed location.
- 3) Work surfaces for seated positions should be approximately 29-31 in. (740-790 mm) above the floor. Therefore, we located all desk heights at 29 in. (740 mm).
- 4) Supervisors do not use the controller CRU-ART system, and it can cause crowding or interruptions around the supervisor's desk. Therefore, we located this equipment in the furthest rack at a shelf height of 45 in. (114 cm) above the floor to accommodate CPU cooling and allow data entry using the keyboard and mouse. This is slightly higher than the recommended standing height of 39-41 in. (100-105 cm), but the amount of interaction by each controller is minimal.
- 5) Facilities should provide equipment pullout trays for CPUs to support maintenance activities. Facilities can locate small CPUs at the bottom of equipment racks, when feasible.
- 6) Facilities should label all equipment appropriately. Among the items that they should clearly label are CPUs, stand-alone keyboards, and the buttons corresponding to each system on the KVM switch.
- 7) Facilities should locate equipment and components so that injury to personnel, equipment damage, or inadvertent actuation is minimized. We lowered the shelf holding the WARP, and we placed CPUs on the lowest shelf, when feasible.

3.3 Working Group Recommendations

The WG met for 3 days and evaluated the Exterior and Interior baseline VR models. The meeting culminated with recommended configurations for both layouts based on operational suitability and HF guidance. In addition, the WG generated a model of a centralized supervisor work area that facilities may implement operationally in the future. The following sections present the results for each of the layouts.

3.3.1 Exterior Layout

Facilities demonstrated considerable uniformity in the arrangement of equipment in the Exterior layout. Therefore, the WG developed a single recommendation for the arrangement of equipment for this configuration.

Figure 4 presents a screenshot of the VR model of the proposed SWS for the Exterior layout, with the desk located adjacent to the left side of the operations area. Placing the desk adjacent to the right side of the operations area would reverse the location of the equipment. The administrative monitor is located on the right side of the desk on top of an eight-way KVM switch. The KVM switch connects the administrative, supervisor CRU-ART, and ESIS applications so that all of these systems share a single display, keyboard, and mouse. We located the keyboard and mouse in a pullout tray under the center of the desk. There is a mounting pole located on the left side of the desk that supports the ERIDS (top) and TSD (bottom) monitors. This location

does not obstruct the supervisors' view of the operations floor and permits them to orient the displays for viewing in the operations area. The displays for ERIDS and TSD share the administrative system keyboard and mouse via the KVM switch. Supervisors and maintenance personnel will label all CPUs and keyboards for easy identification.

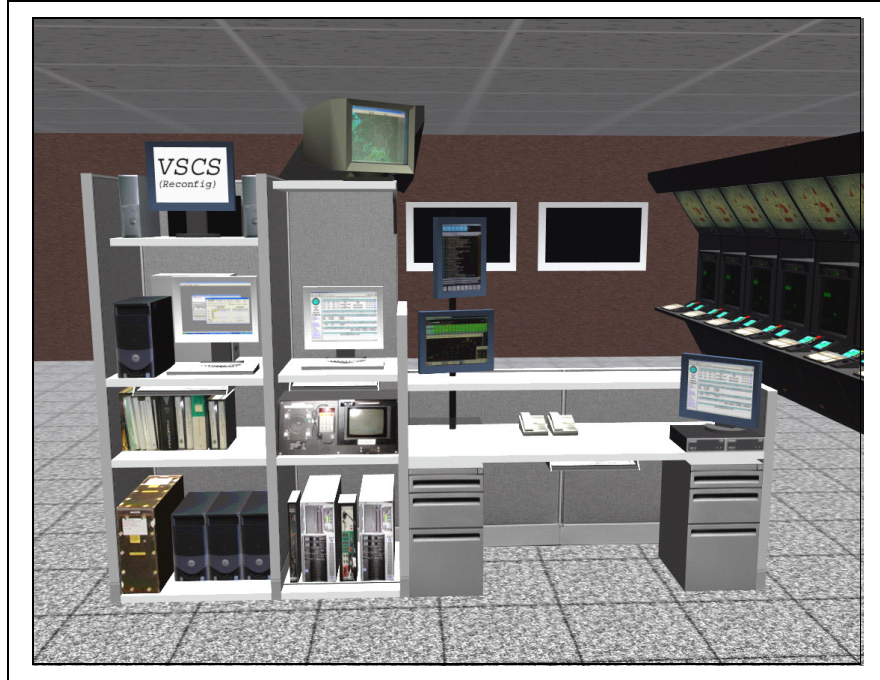


Figure 4. Recommended design of the SWS for the Exterior layout.

Beginning at the top of the rack closest to the supervisor and working down, the equipment shown is the WARP display, the ERAM display, the ERAM keyboard, the WARP keyboard (in a pullout tray), the VSCS VDM, and the ERAM CPUs. The shelf holding the ERAM display and keyboard is 45 in. (114 cm) above the floor to support data entry using the keyboard. We were able to lower this shelf to an acceptable height by incorporating a single display version of the VSCS VDM unit, which has reduced height requirements. We placed the ERAM CPU on a pullout tray to promote accessibility and support maintenance activities.

The top shelf of the second equipment rack houses the ERIDS CPU, VSCS reconfiguration display, and the WARP CPU. The supervisor CRU-ART CPU is located behind the VSCS reconfiguration display. The next shelf supports the controller CRU-ART CPU, display, and keyboard. The VSCS reconfiguration CPU is located behind the controller CRU-ART display. We located the controller CRU-ART in this rack to minimize disruption and traffic flow at the supervisor's desk. The shelf is 45 in. (114 cm) above the floor to promote usability of the keyboard by a standing operator. Attached beneath this shelf is a pullout tray holding the VSCS reconfiguration keyboard and trackball. The next shelf either holds paper reference materials or can be used for flight strip printers. Located at the bottom of the rack on a pullout tray are the CPUs for the VSCS VDM, ESIS, TSD, and the administrative system.

3.3.2 Interior Layout

Another common arrangement in the field today is to seat supervisors in the operations area facing the main aisle with the supervisor's back to the operation area. The objective of this configuration is to minimize noise and distraction from the main aisle. This is typically accomplished by using a 68 in. (172.7 cm) to 84 in. (213.4 cm) cubicle wall behind the supervisor's desk. Besides differences in wall height and length, this configuration results in vastly different layouts across facilities. As a result, the WG developed three different Interior layout options to address each of these variations. In this report, we describe two of the options: one using the existing Associate-side (A-side) controller console and the other using an equipment rack. The WG proposed a third option using a Crenlo rack, but rejected it because it was significantly more expensive than the first two options.

Figure 5 presents a VR model of the proposed Interior layout utilizing the existing A-side console equipment. The location of equipment is reversed if the SWS is located on the other side of the operations area. As illustrated in Figure 5, the picture on the left shows the SWS, and the picture on the right shows the equipment rack outside the work space.

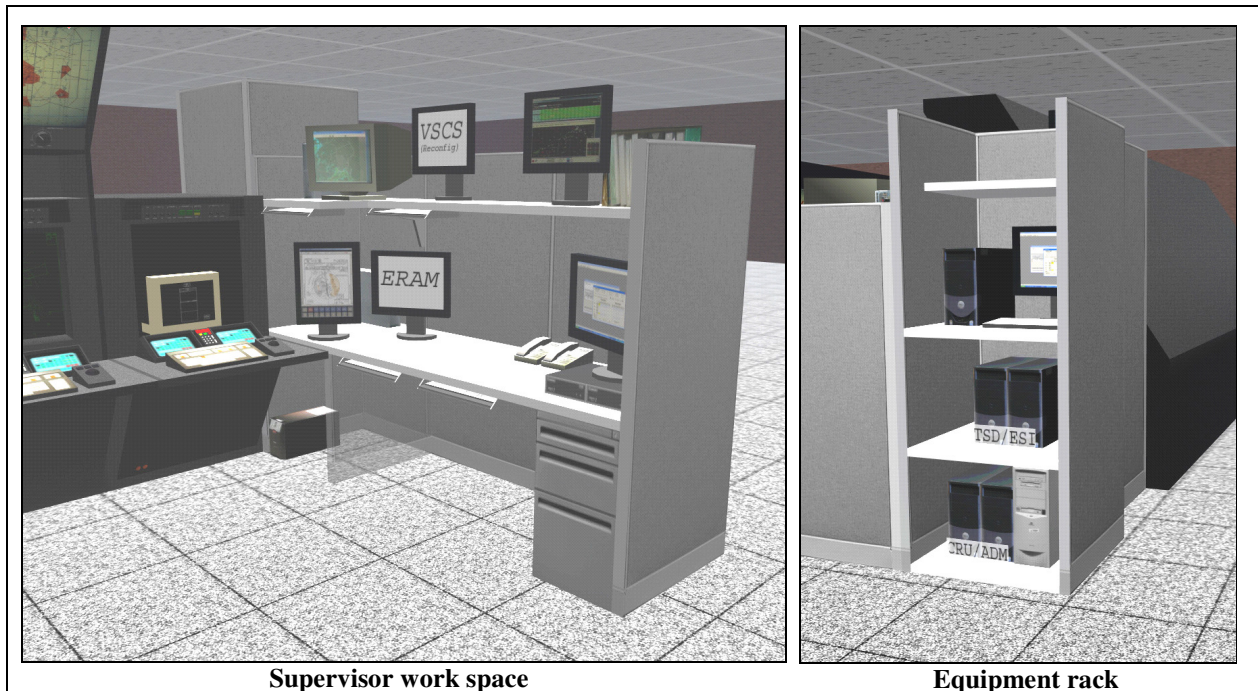


Figure 5. Recommended design of the SWS for the Interior layout.

The administrative monitor is located on the right side of the desk on top of an eight-way KVM switch. The KVM connects the administrative, supervisor CRU-ART, and ESIS applications so that all of these systems share a single display, keyboard, and mouse. The two remaining monitors on the desk are for ERAM (left) and ERIDS (farthest left). The ERIDS CPU is located behind the ERAM display. There are two pullout trays under the desk. The pullout tray on the right holds the keyboard and mouse that is connected to the KVM. The ERIDS and the TSD are also connected to the KVM and use the same keyboard and mouse. The other pullout tray holds the ERAM keyboard. The upper shelf holds the reference materials, the TSD monitor, the VSCS

reconfiguration monitor, the WARP monitor, and the WARP CPU. The input devices for the VSCS reconfiguration system are located on a pullout tray directly beneath its display. Similarly, the keyboard for the WARP system is located in a pullout tray directly beneath its display. To facilitate identification, all CPUs and keyboards are labeled.

The existing A-side console that is located to the left of the supervisor's desk remains in place, with the VSCS VDM intact. The ERAM CPU and its associated equipment (not visible) are located in the bottom of the A-side console on a pullout tray to promote accessibility in support of maintenance activities.

The equipment rack depicted in the right side of the figure is not visible from the SWS. It is parallel with the existing DSR workstations and facing the main aisle. The rack is the same model and style of furniture used in the SWS to avoid the cost of replacing the existing furniture. Some facilities using the Interior layout already have this rack. In the new design, the top of the rack is for reference materials or other site-specific needs. The second shelf holds the controller CRU-ART monitor, CPU, and keyboard. It is approximately 45 in. (114.3 cm) above the floor to promote usability of the keyboard by a standing operator. The next lowest shelf holds the TSD and ESIS CPUs. The supervisor CRU-ART, admin, and VSCS reconfiguration CPUs are located in the bottom of the rack on a pullout tray.

In the alternate layout developed by the WG, a standard equipment rack replaces the A-side console shown in Figure 5. This rack holds the VSCS reconfiguration monitor (top), ERAM display (second shelf), VSCS VDM unit (third shelf), and ERAM CPUs (bottom). The design of the supervisor's desk and equipment rack remain as depicted in Figure 5.

3.3.3 Centralized Layout

The WG developed a model for the Centralized command concept (see Figure 6). In the proposed design, supervisors are collocated in an area near the middle of the operations floor. The goal of this design is to promote inter-area communications between supervisors. By being in close proximity to one another, supervisors will be able to more effectively coordinate traffic routing and maintain greater team situation awareness. This design also makes a centrally located desk, TSD, and VSCS available to the Traffic Management Unit (TMU). The TMU could staff this position during times they considered advantageous to have a team member on the operations floor. These likely would include periods of traffic management restrictions and adverse weather conditions. This layout includes provisions for four controller SISO workstations. The recommended keyboard height is approximately 40 in. (101.6 cm) from the floor because it is a standing workstation. This workstation could also provide space for WARP or other weather displays, flight strip printers, paper reference materials, and other required materials.

The SWS layout shares many of the same design characteristics of the previous models, including the use of an eight-way KVM switch, display sharing, and the labeling of all CPUs and standalone keyboards. As in the Interior and Exterior layouts, the administrative, supervisor CRU-ART, and ESIS applications are shared on the administrative display. Besides the benefits to coordination and communication, this concept affords the opportunity for two supervisors to share the same VSCS and possibly ERAM equipment, resulting in substantial cost and space savings. The CPUs for ERAM and all computer systems are located under the supervisor's desk on pullout trays.



Figure 6. Recommended design of the SWS for the Centralized layout.

4. DISCUSSION

The survey of the FAA ARTCCs indicated that there are up to eight computer-based systems that area supervisors use to perform their operational and administrative tasks. The supervisors reported using the systems (either monitoring or interacting with them) approximately 50% of the time during a typical shift, although there were variations in the time estimates. Not all areas have all the systems in the immediate SWS (e.g., some are shared between areas) and, in many cases, multiple systems share a display monitor and input device. With three exceptions, the responding supervisors complained (a) that their work spaces were cluttered with the systems and other work equipment and materials and (b) that the placement of the systems made it difficult to read the displays, to access the input devices, and to maintain the equipment. ERAM and ERIDS will add more systems, possibly requiring a reorganization of the existing systems, so their placement in the SWS needs to be carefully considered to optimize their use.

The survey responses confirmed the two basic layouts of the SWS, although there are variations in which systems are included and where they are located. The most common layout was for the supervisor's desk to be perpendicular to the controller workstation bay with the supervisor seated in the main aisle looking into the bay. Typically, this Exterior SWS had two equipment racks to the side of the desk and outside the bay; there were normally three shelves on each rack. The second most common layout also had the desk perpendicular to the bay, but the supervisor was seated inside the bay. The desk was longer (essentially an equipment rack) and had at least one shelf running the full length of the desk for the computer systems and other materials and equipment. The supervisor also could use the controller workstation immediately beside the

desk. Other variations placed the supervisor's desk either parallel to or perpendicular to the bay, with controller workstations in front and behind the supervisor. We considered both of these variations to be functionally similar to the Exterior layout.

The HF Team researchers were able to effectively implement the general HF principles into the baseline VR models. By using VR modeling, the HF Team interactively developed operationally viable solutions for the WG to consider. The VR models presented highly realistic representations of the SWS that enabled equipment placement based on space requirements as well as accessibility, field of view, and other HF considerations. The next task, WG review of the baseline layouts, also benefited from use of the VR models. For example, they evaluated the ability to view supervisor displays and the operations floor by moving within the virtual environment. This capability was particularly beneficial when developing the Centralized control concept. As a new, non-implemented concept, the group could not rely on their past experience in ARTCC facilities. By immersing themselves in the virtual environment, they were able to see that in the original design concept, the supervisor did not have an acceptable view of the operations floor. By moving the desks farther apart, they were able to identify a new configuration that provided an acceptable view of the operations floor and still meet equipment access and right-of-way requirements.

This project culminated with recommendations for the layout of SWS areas based on the prevalence of the current configuration, cost of implementation, ease of implementation, and other logistic considerations. Although the Exterior layout is the WG's preferred design, there was not sufficient cause to limit the flexibility of operational facilities to maintain an Interior layout, should they choose to implement it. Facilities may prefer the Centralized layout in the future because of its potential to reduce equipment costs, to promote inter-area communications, and to provide other benefits.

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Acronyms

ARTCC	Air Route Traffic Control Center
A-side	Associate-side
ATC	Air Traffic Control
CIWS	Corridor Integrated Weather System
CPU	Computer Processor Unit
CRU-ART	Controller Work Tracking System
DOD	Department of Defense
DSR	Display System Replacement
ERAM	En Route Automation Modernization
ERIDS	En Route Information Display System
ESIS	Enhanced Status Information System
ETMS	Enhanced Traffic Management System
FAA	Federal Aviation Administration
HF	Human Factors
KB	Keyboard
KVDT	Keyboard Video Display Terminal
KVM	Keyboard, Video, and Mouse
Reconfig	Reconfiguration
SISO	Sign in/Sign out
SUPCOM	Supervisor Committee
SWS	Supervisor Work Space
TB	Trackball
TMU	Traffic Management Unit
TSD	Traffic Situation Display
UPS	Uninterruptible Power Supply
VDM	Video Display Module
VR	Virtual Reality
VSCS	Voice Switching and Control System
WARP	Weather and Radar Processor
WG	Working Group

Appendix A
En Route Supervisor Workstation Survey

En Route Supervisor Workstation Survey

Area or Specialty Identifier(s): _____ Date: _____

1) Equipment Checklist

a) During a typical shift, what percentage of the time do supervisors use computer systems? _____%

b) In the table below, rate how often you use the equipment or display in a typical shift. Use the following scale:

N/A – Not Available

1 – Almost Never Used less than 1 time per shift.

2 – Rarely Used 1-2 times per shift for short periods of time.

3 – Occasionally Used several times per shift for short periods OR 1-2 times for lengthy periods.

4 – Frequently Used several times for lengthy periods OR numerous times for short periods.

5 – Very Frequently Used numerous times for lengthy periods.

c) Indicate the size (i.e., diagonal measurement in inches) of the monitors at these areas.

Equipment	b) Frequency of use						c) Display size
	N/A	1	2	3	4	5	
a) SUPE admin. PC	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____ inches
b) TSD	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____ inches
c) Weather display	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____ inches
d) Cru-ART	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____ inches
e) KVDT	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____ inches
f) VSCS	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____ inches
g) ERIDS	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____ inches
h) A/B switch	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____ inches
i) Other _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____ inches
j) Other _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	_____ inches

d) Identify any systems that share the same monitor or input device: _____

e) Identify any systems that are shared between areas/specialties: _____

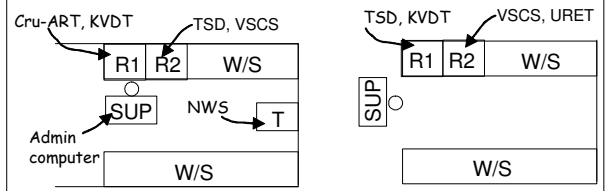
f) What is the width of the center aisle? _____

2) Floor plan

In the space below, draw a floor plan of this area showing the following equipment (see examples below)

- a) Controller en route workstations ()
- b) Supervisor desk/workstations ()
- c) Supervisor work location ()
- d) Equipment racks ()
- e) Tables ()

Examples

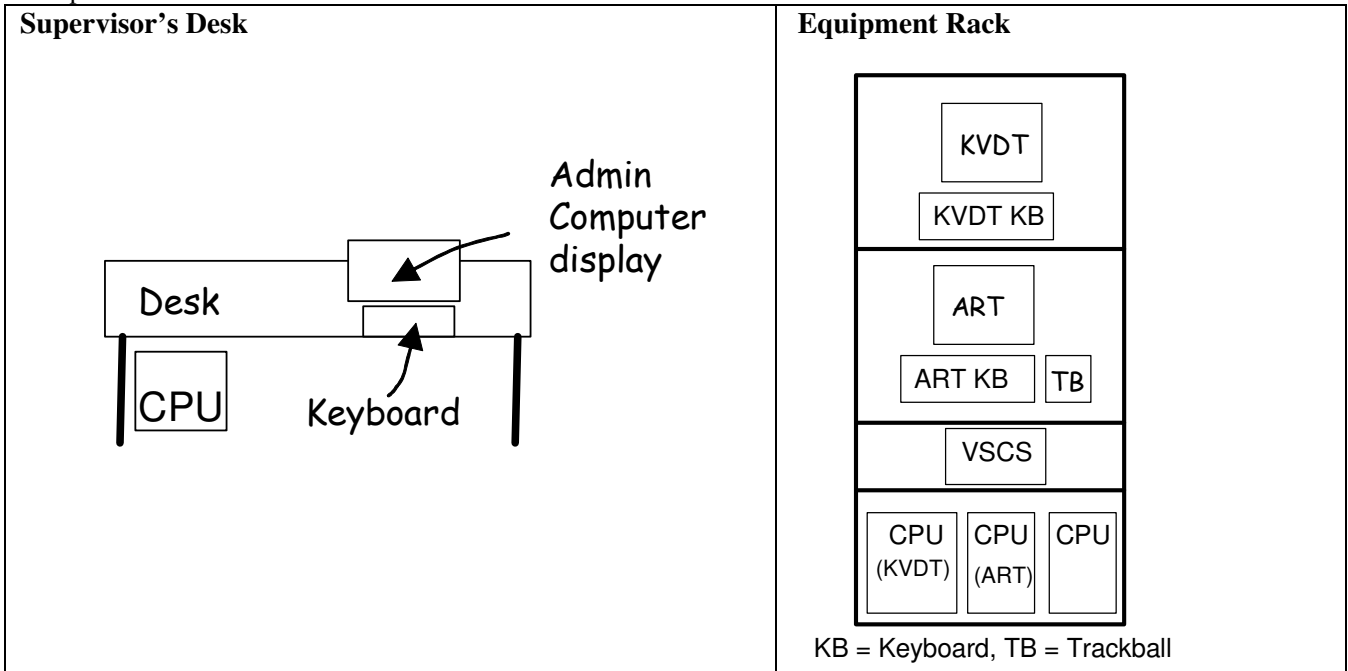


Identify the location of the equipment from the equipment checklist as shown in the example

3) Equipment Configuration

Draw a sketch of the location of the CPUs, displays, input devices, and monitors for equipment at the following locations. See sample drawings below.

Examples



a) Supervisor's Desk (include the location of CPUs, displays, input devices, and monitors)

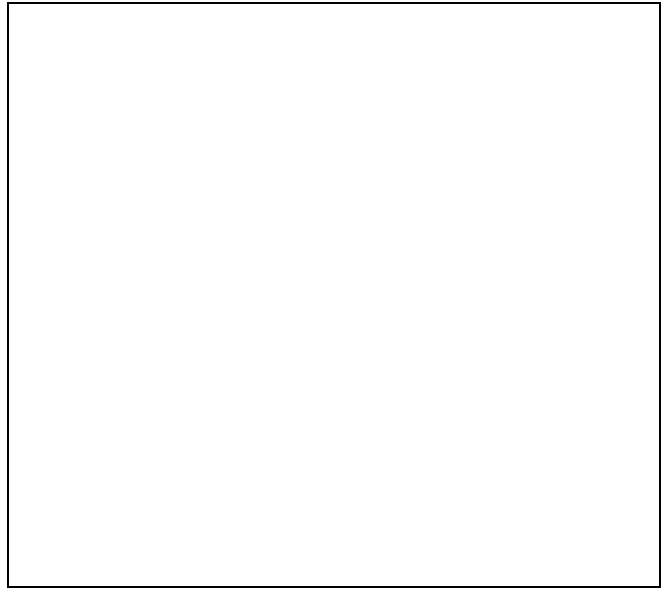
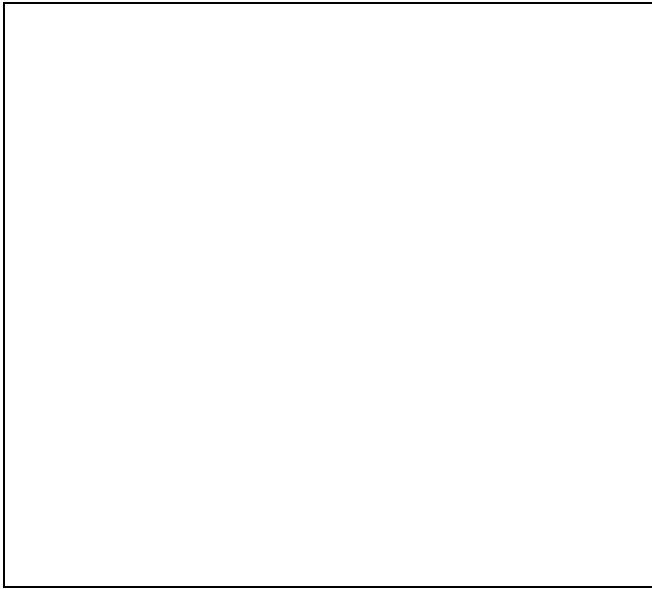
What is the height of the supervisor's desk? _____

Identify the configuration of equipment as shown in the example above.

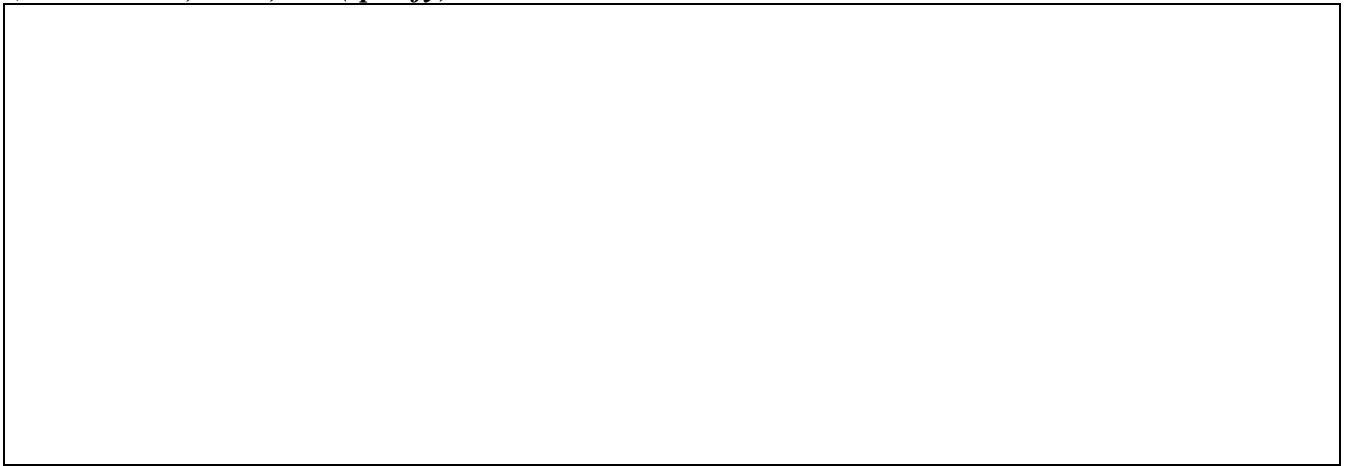
Draw a sketch of the following locations including the location of CPUs, displays, input devices, and monitors.

b) Equipment Rack 1

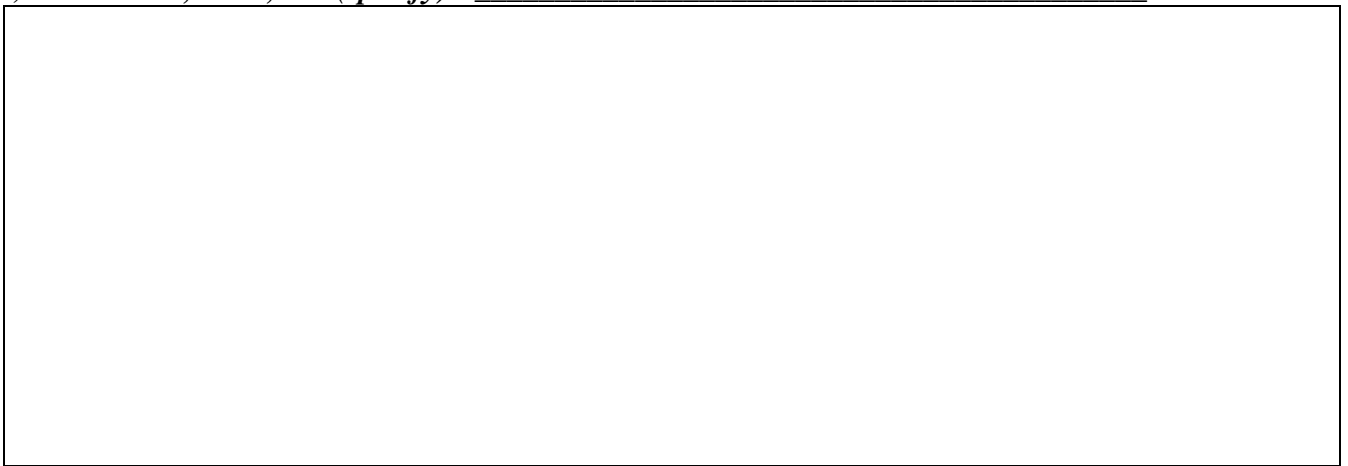
c) Equipment Rack 2



d) Other rack, table, etc. (*specify*): _____



e) Other rack, table, etc. (*specify*): _____



f) Other rack, table, etc. (*specify*): _____



4) General Questions

a) **What are the major problems with the design or layout of the supervisor workstation in these areas?** Identify problems related to total space available, organization of equipment, readability, ease of use, etc. Please be as specific as possible (e.g., the TSD is too far away to read when seated at the desk).

b) **If any of the systems, displays, or keyboards difficult to monitor or access, please identify the equipment and describe the issue, including maintenance issues.**

c) **Do you have any other comments or suggestions regarding the supervisor's workstation or work area?**

Thank you for your participation

Your responses will aid in the design and layout of future En route supervisor workstations.

If you have any questions contact:

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Appendix B
En Route Supervisor Workstation Layouts

Appendix B: En Route Supervisor Workstation Layouts

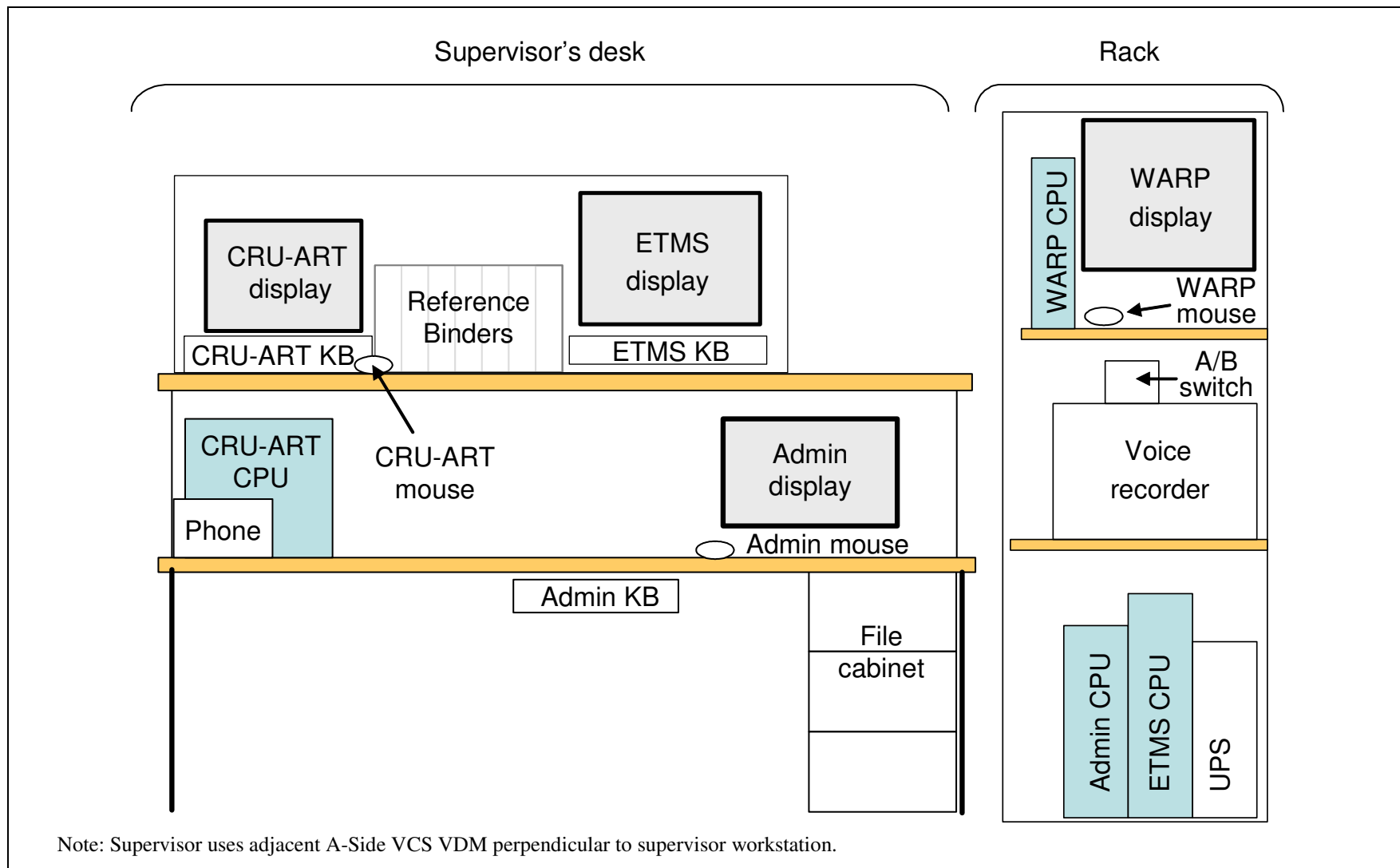
This appendix presents the equipment layouts as provided by the facilities in response to the SWS survey. The schematics are based on the drawings, written comments, and photographs received in response to the survey. The responses varied substantially in content and level of detail, so the schematics reflect our best interpretation using the data available. In some cases we received responses for more than one but not all the areas in a center, without an indication of how many areas were similar to each layout. The survey instructions requested that the facility submit a separate schematic for each variation, therefore we believe that these schematics represent virtually all the configurations at the time of the survey.

We provide a list of the equipment acronyms at the end of this section to aid in identifying the specific equipment depicted in the figures. We organized the schematics by type of facility layout (i.e., interior, exterior, and split) as follows.

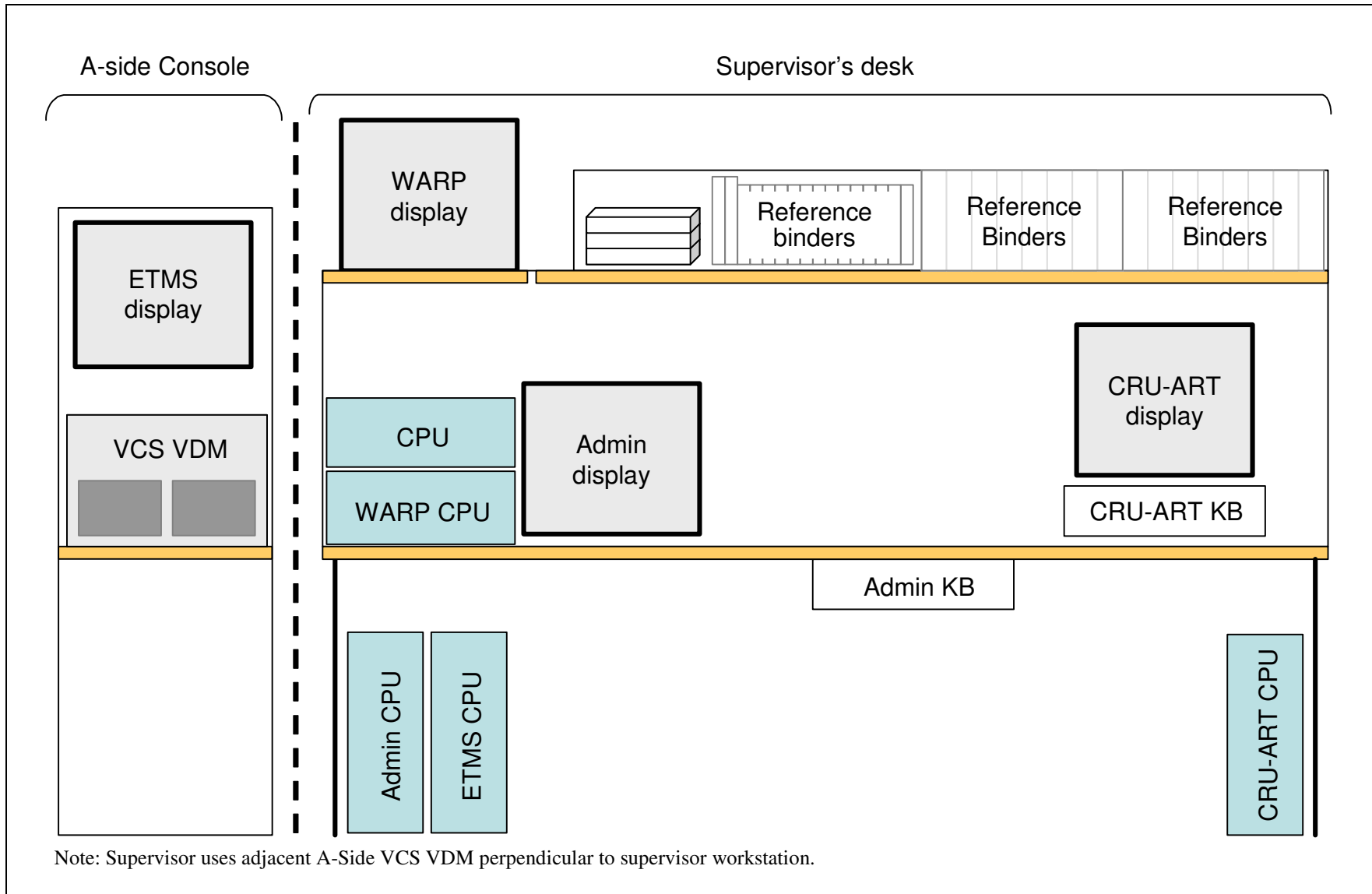
Layout	Supervisor Location	Facility
Interior	Seated with back to area	<ul style="list-style-type: none"> • ZAB (Albuquerque ARTCC) • ZFW (Fort Worth ARTCC) • ZID (Indianapolis ARTCC) • ZLA (Los Angeles ARTCC) • ZMP (Minneapolis ARTCC) • ZOA (Oakland ARTCC) • ZOB (Cleveland ARTCC)
Exterior	Seated facing area	<ul style="list-style-type: none"> • ZAN (Anchorage ARTCC) • ZAU (Chicago ARTCC) • ZBW (Boston ARTCC) • ZDC (Washington ARTCC) • ZDV (Denver ARTCC) • ZJX (Jacksonville ARTCC) • ZKC (Kansas City ARTCC) • ZLC (Salt Lake ARTCC) • ZMA (Miami ARTCC) • ZME (Memphis ARTCC) • ZNY (New York ARTCC) • ZSE (Seattle ARTCC) • ZTL (Atlanta ARTCC)
Split	Seated between DSR racks	<ul style="list-style-type: none"> • ZHU (Houston ARTCC)

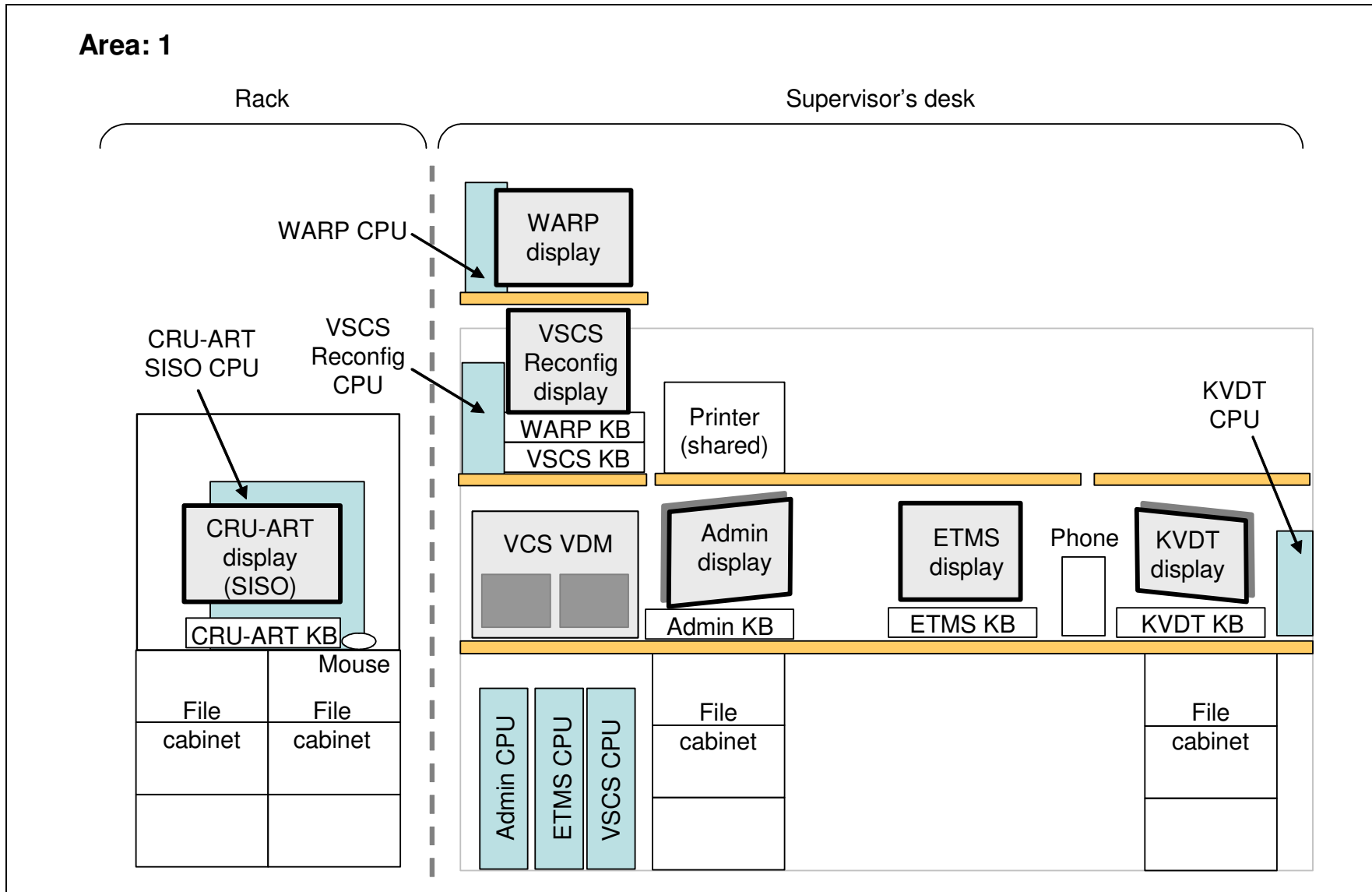
Interior Layout (Supervisor's back to area)

ZAB (Albuquerque ARTCC)



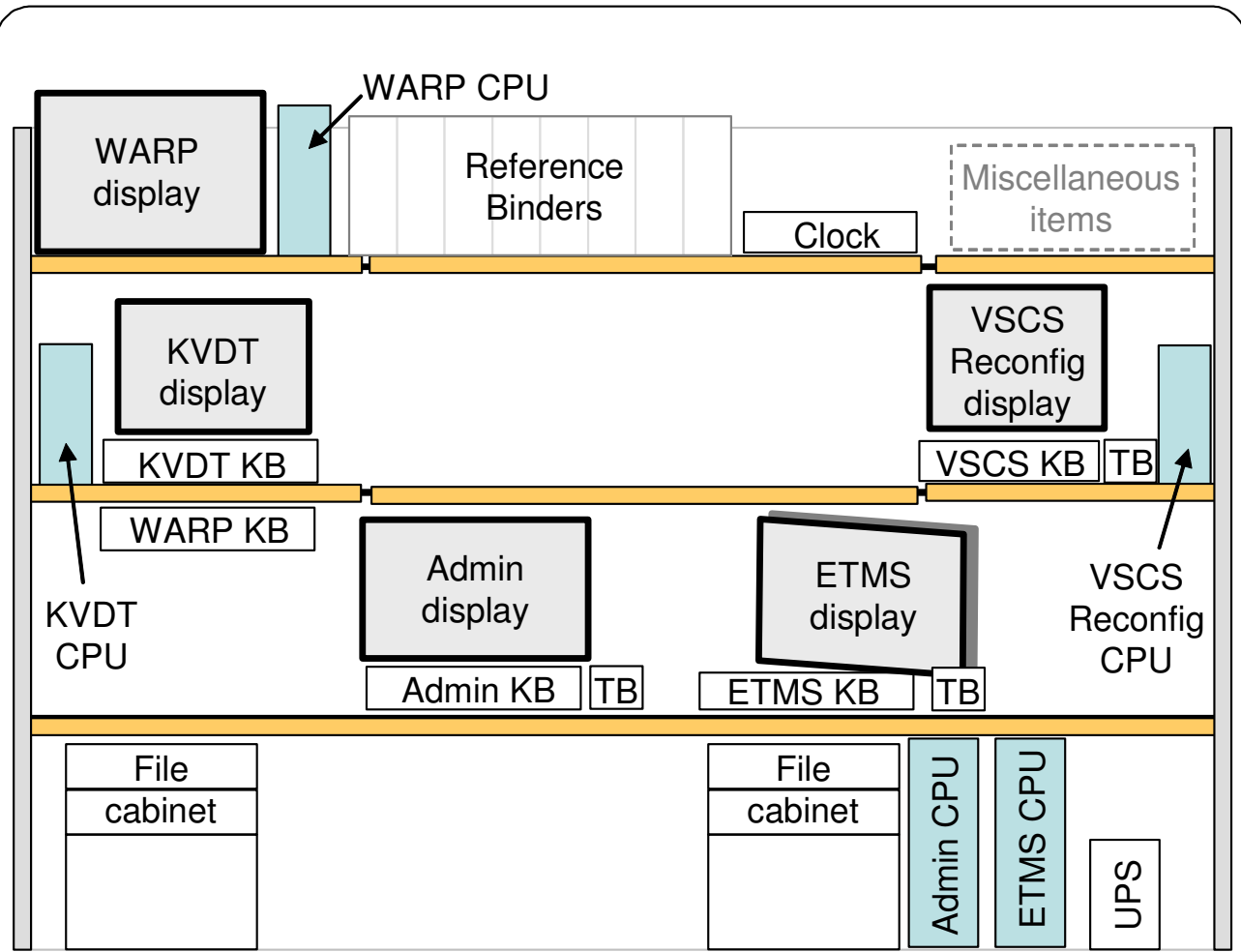
ZFW (Fort Worth ARTCC)

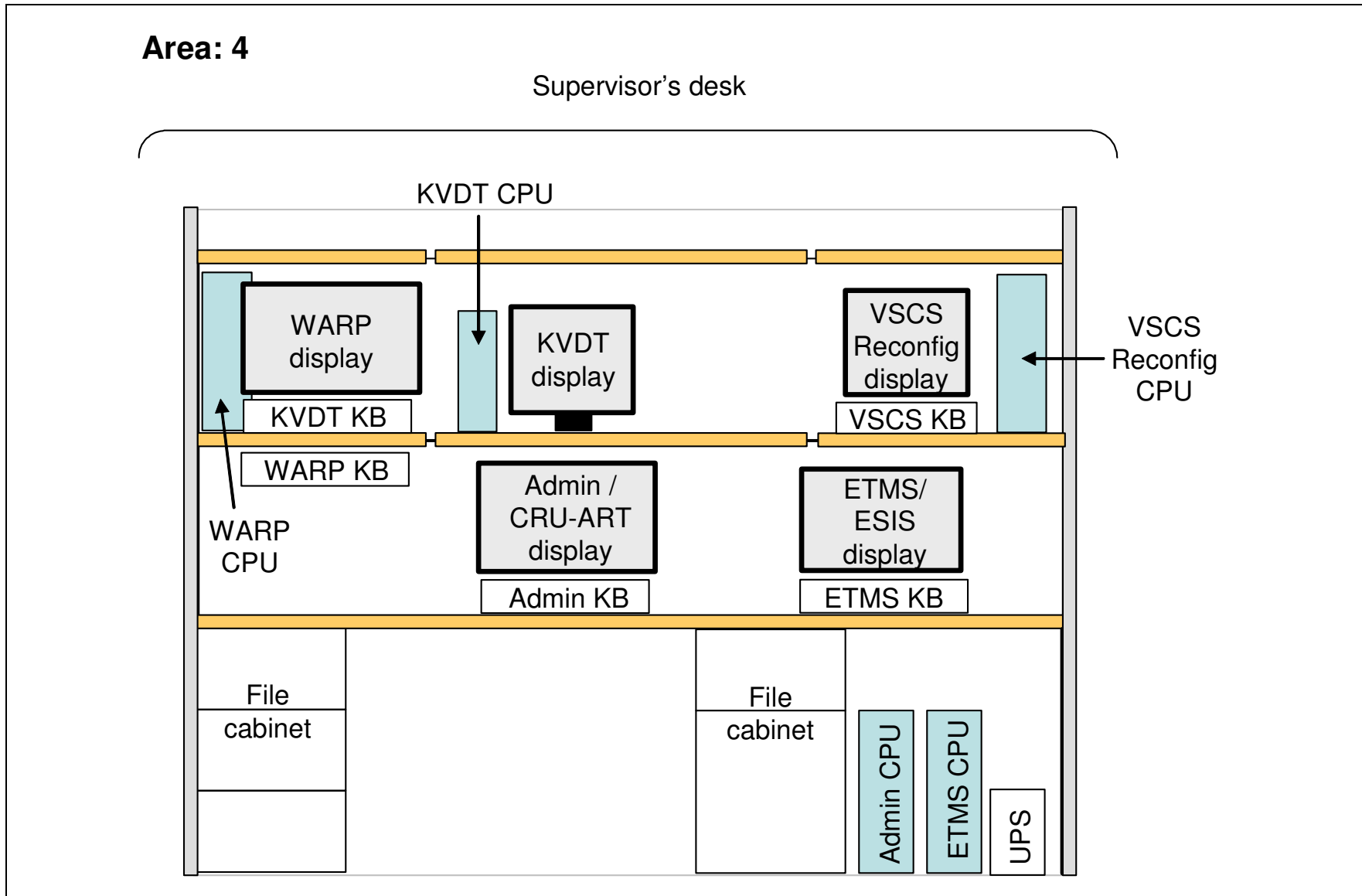




Areas: 2, 3, 5, 6

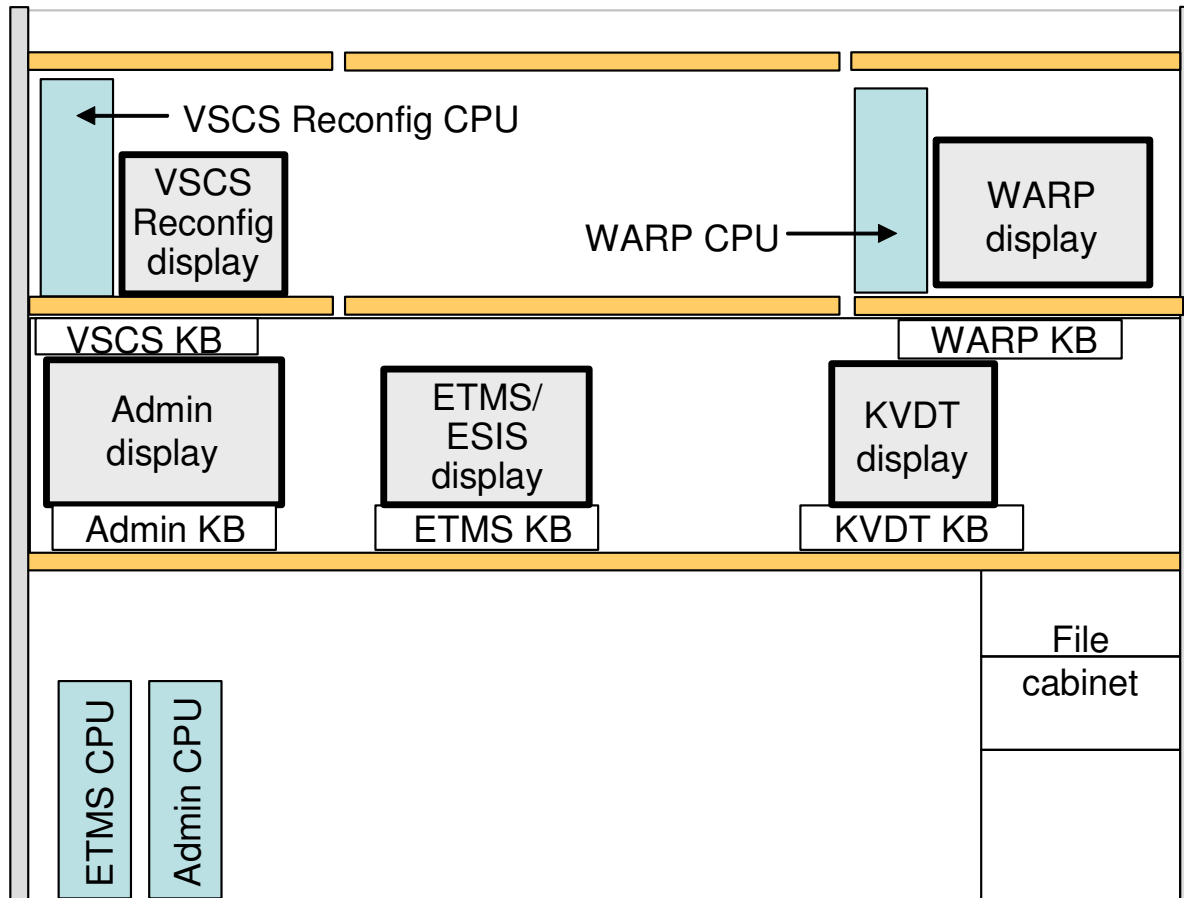
Supervisor's desk



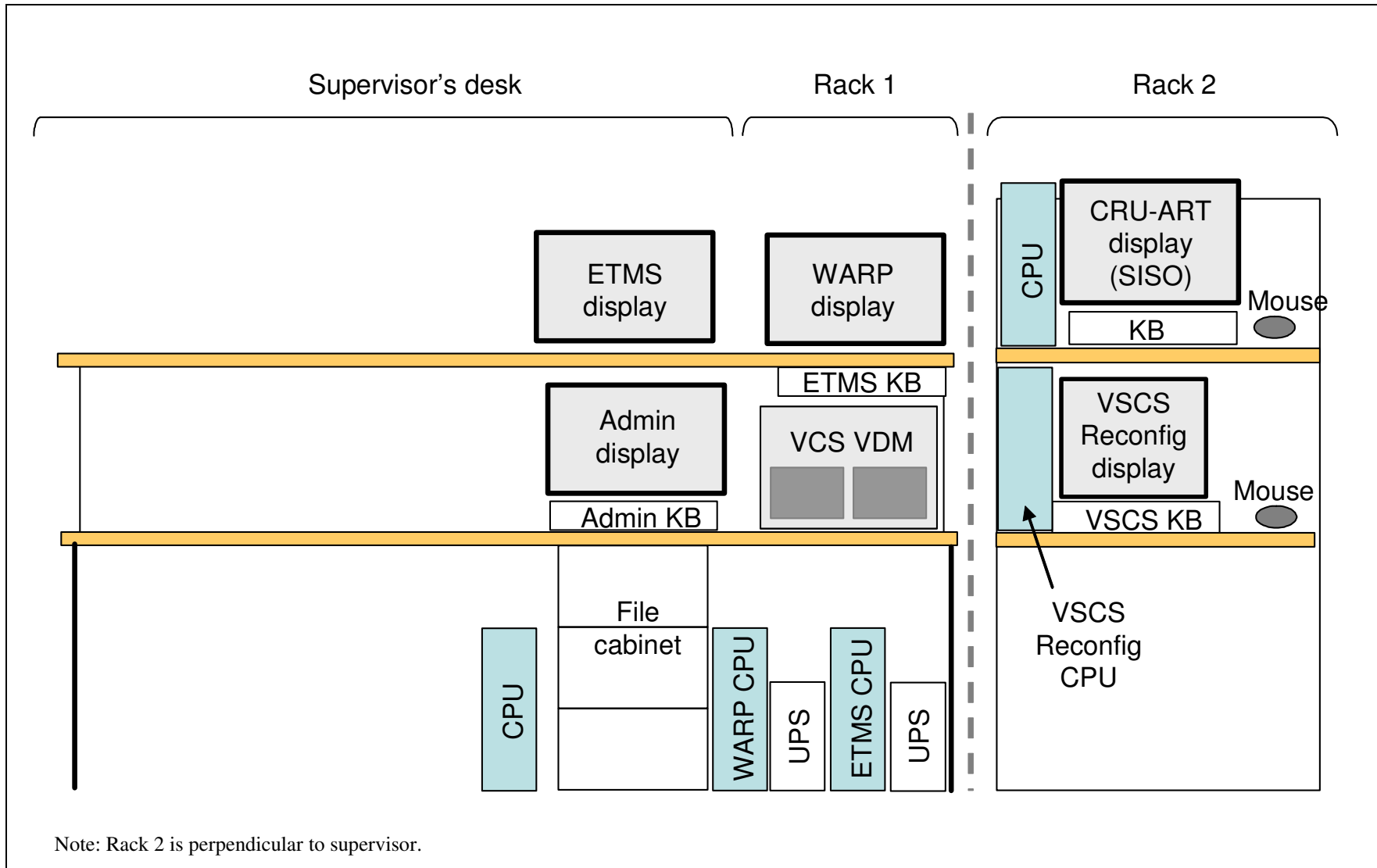


Area: 7

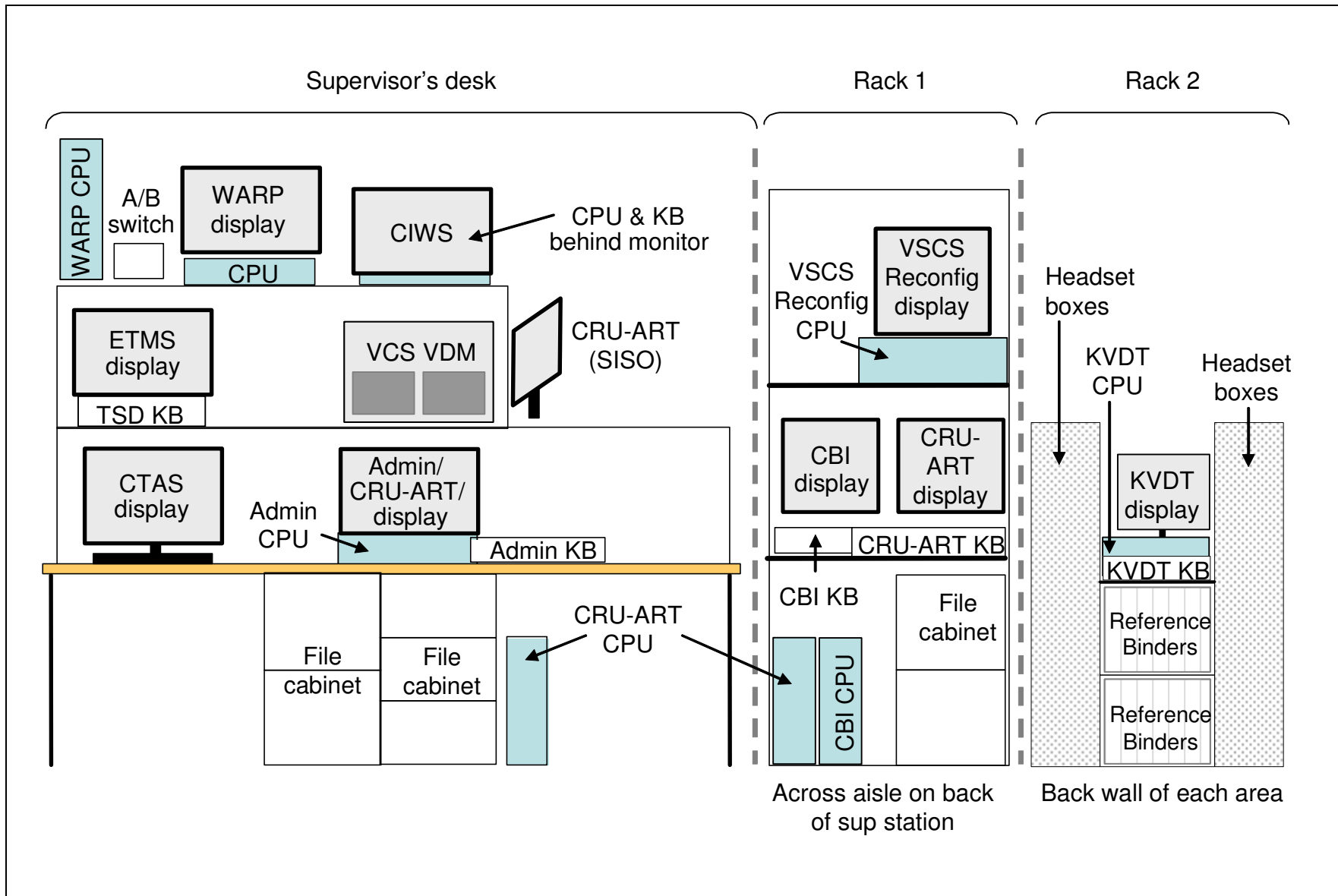
Supervisor's desk



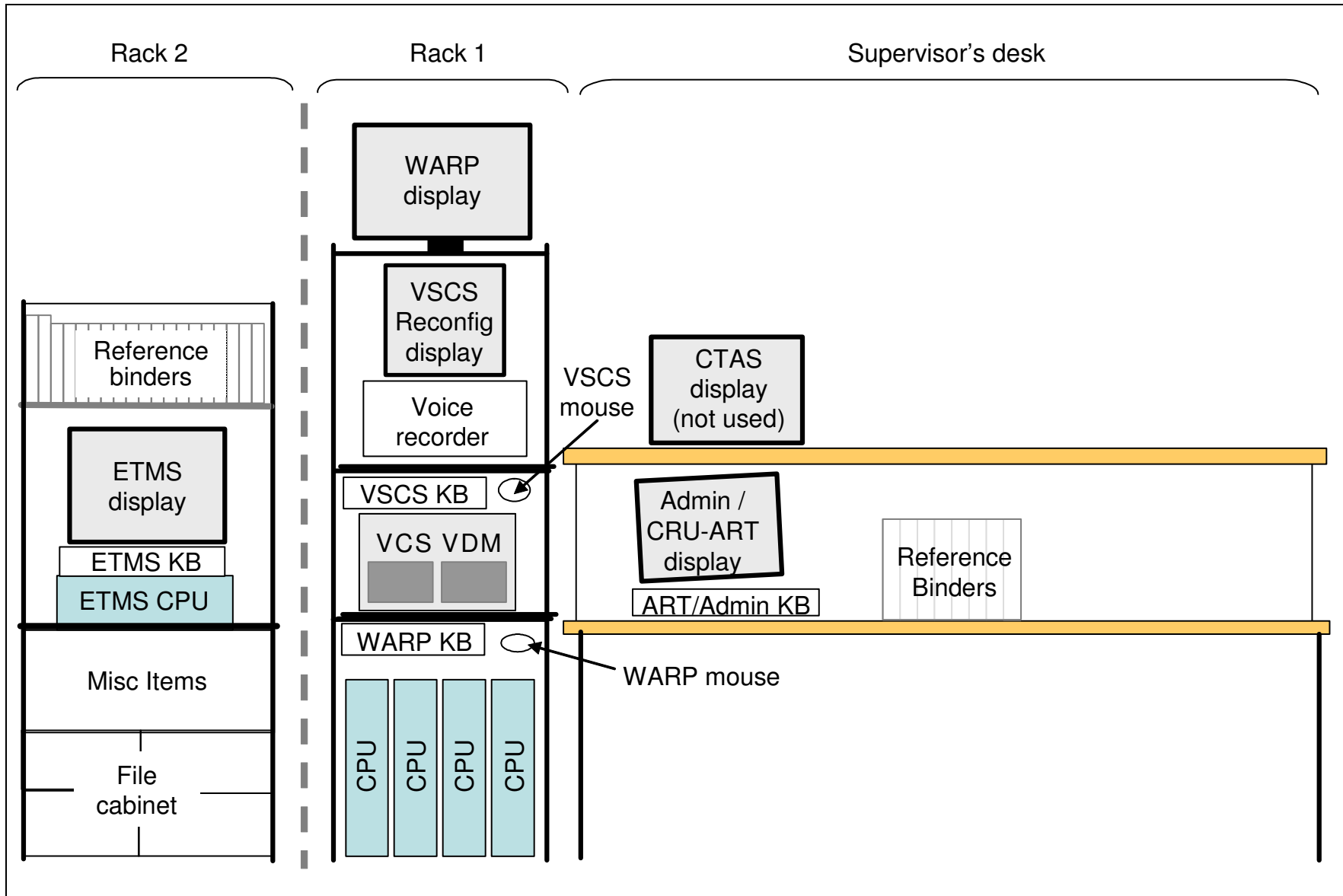
ZLA (Los Angeles ARTCC)

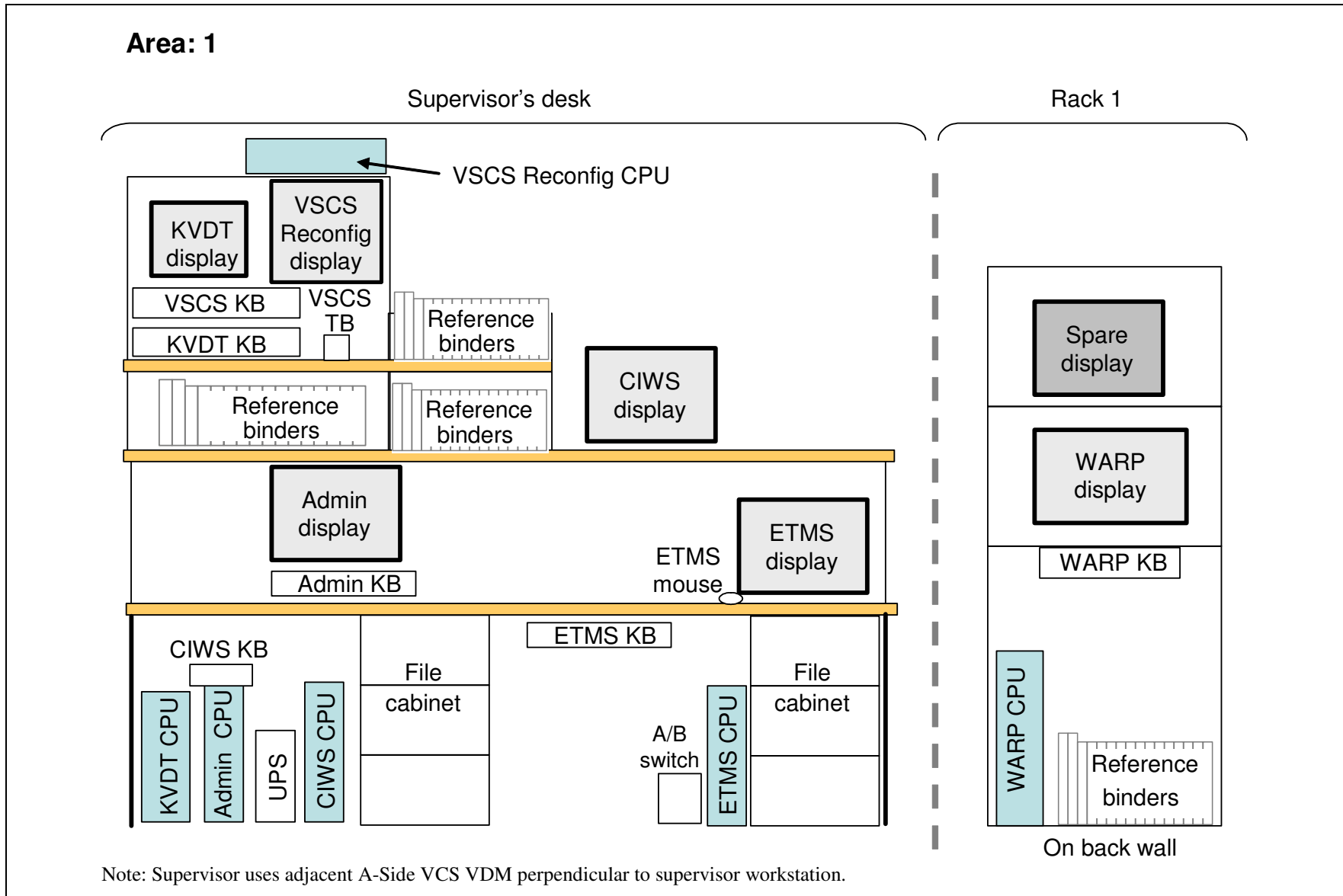


ZMP (Minneapolis ARTCC)



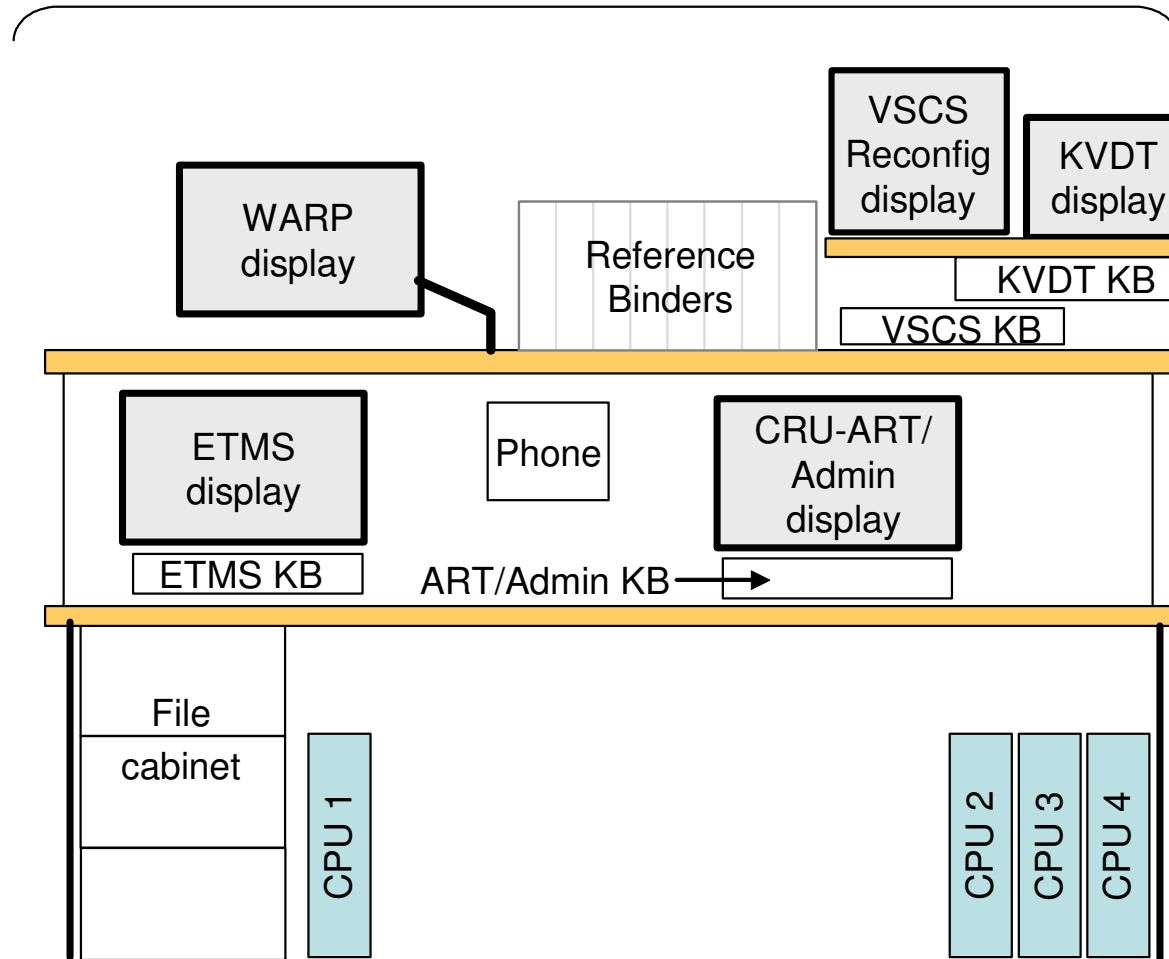
ZOA (Oakland ARTCC)





Area: 6

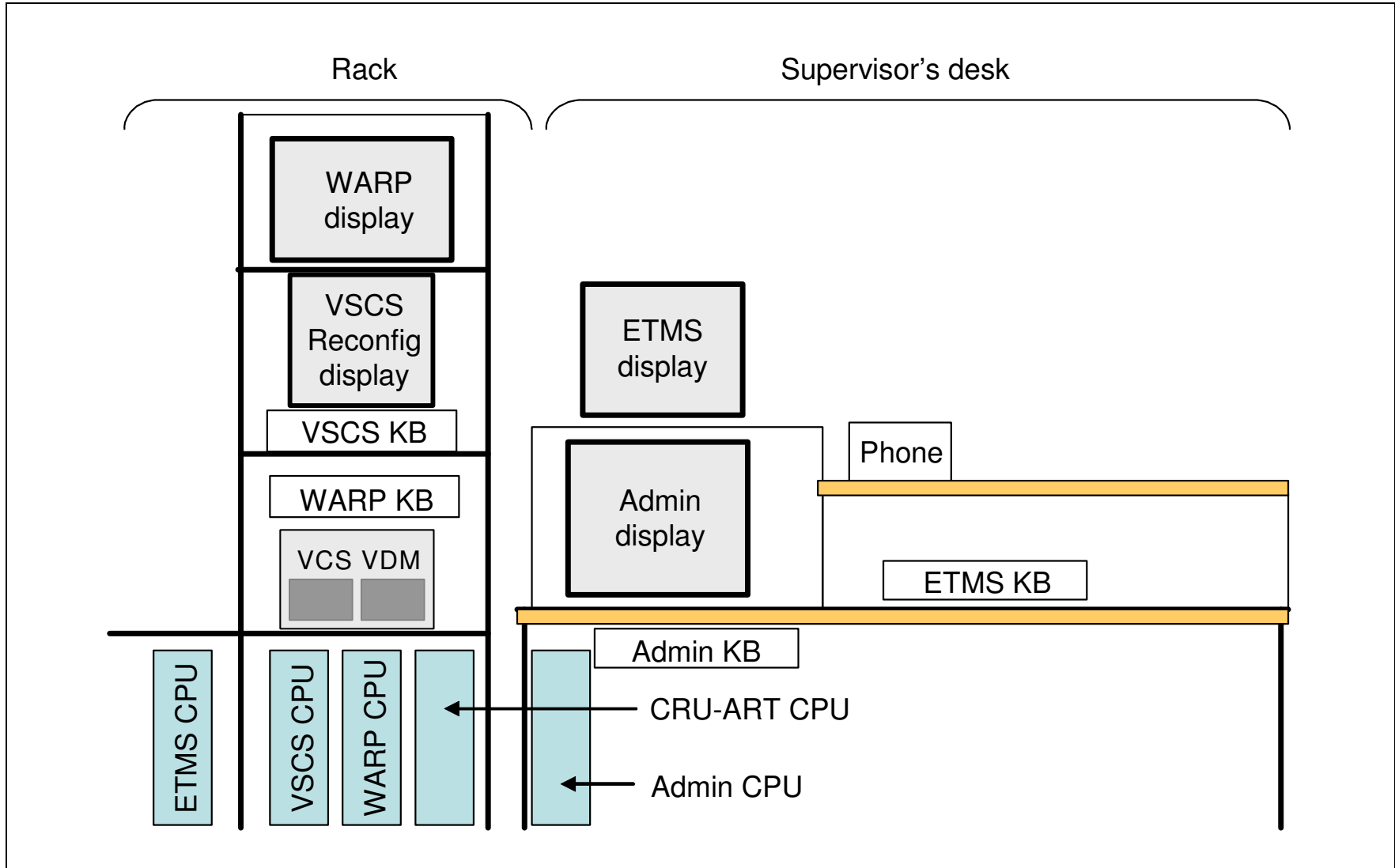
Supervisor's desk

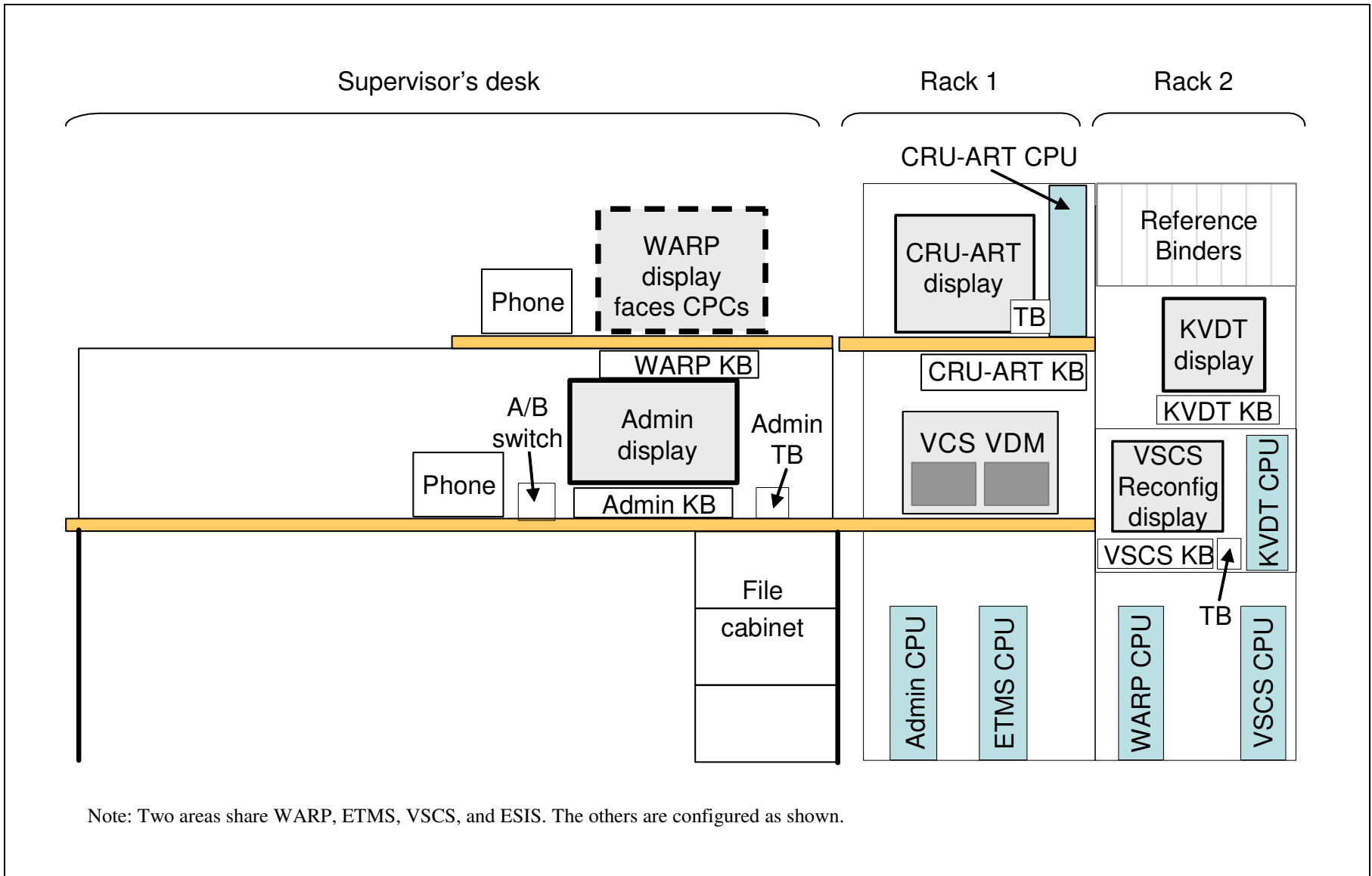


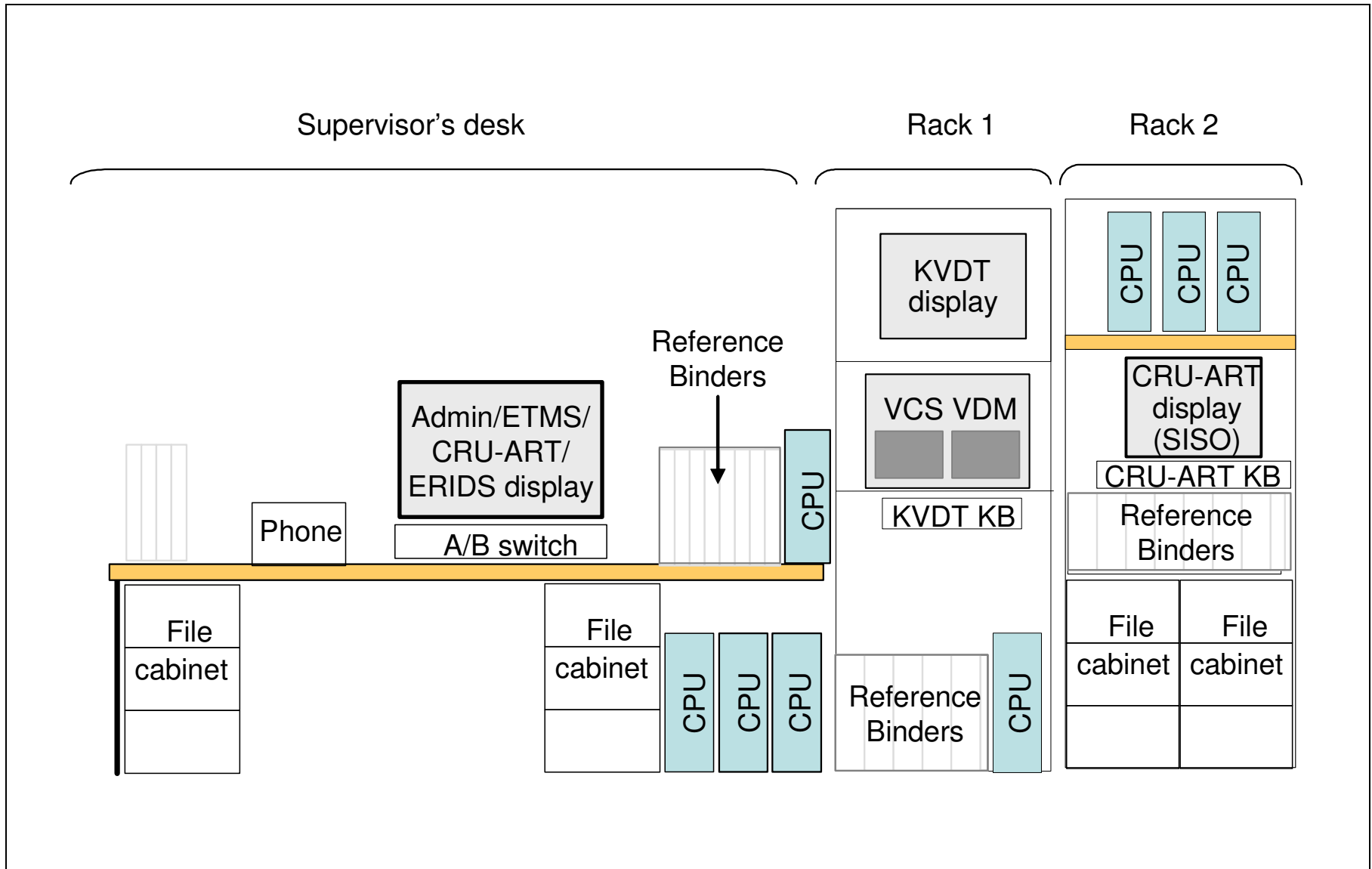
Note: Supervisor uses adjacent A-Side VCS VDM perpendicular to supervisor workstation.

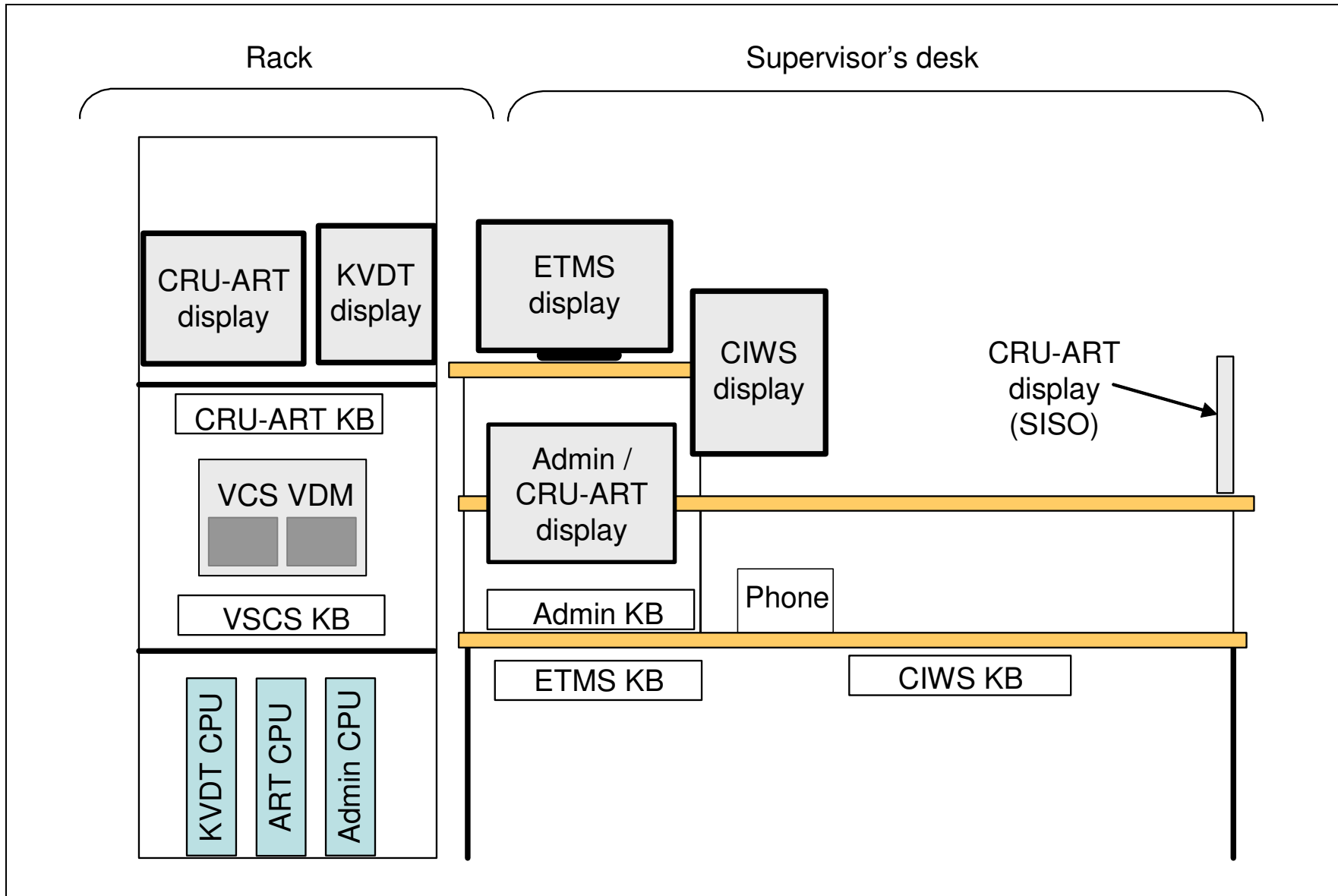
Exterior Layout (Supervisor facing area)

ZAN (Anchorage ARTCC)

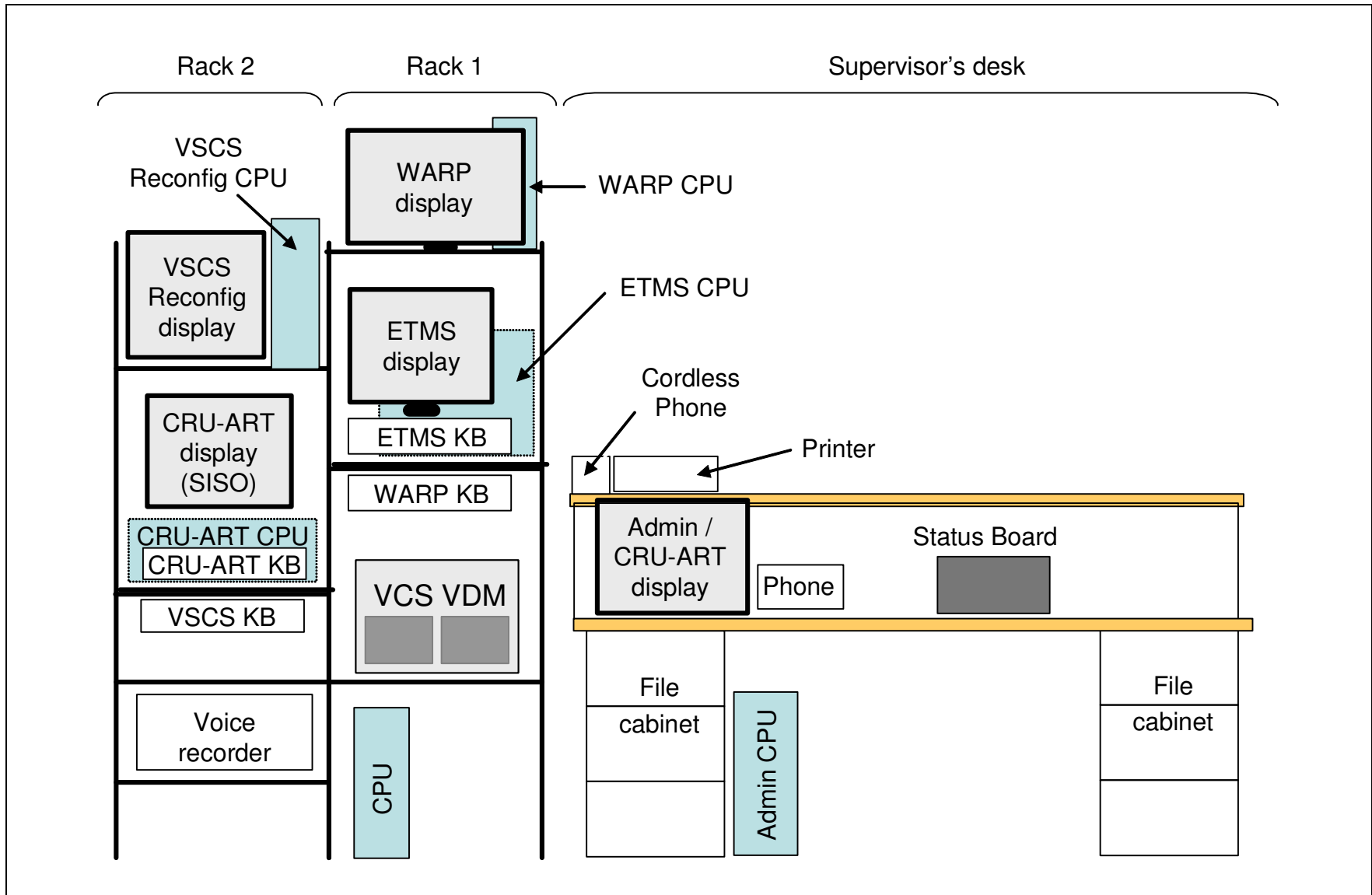


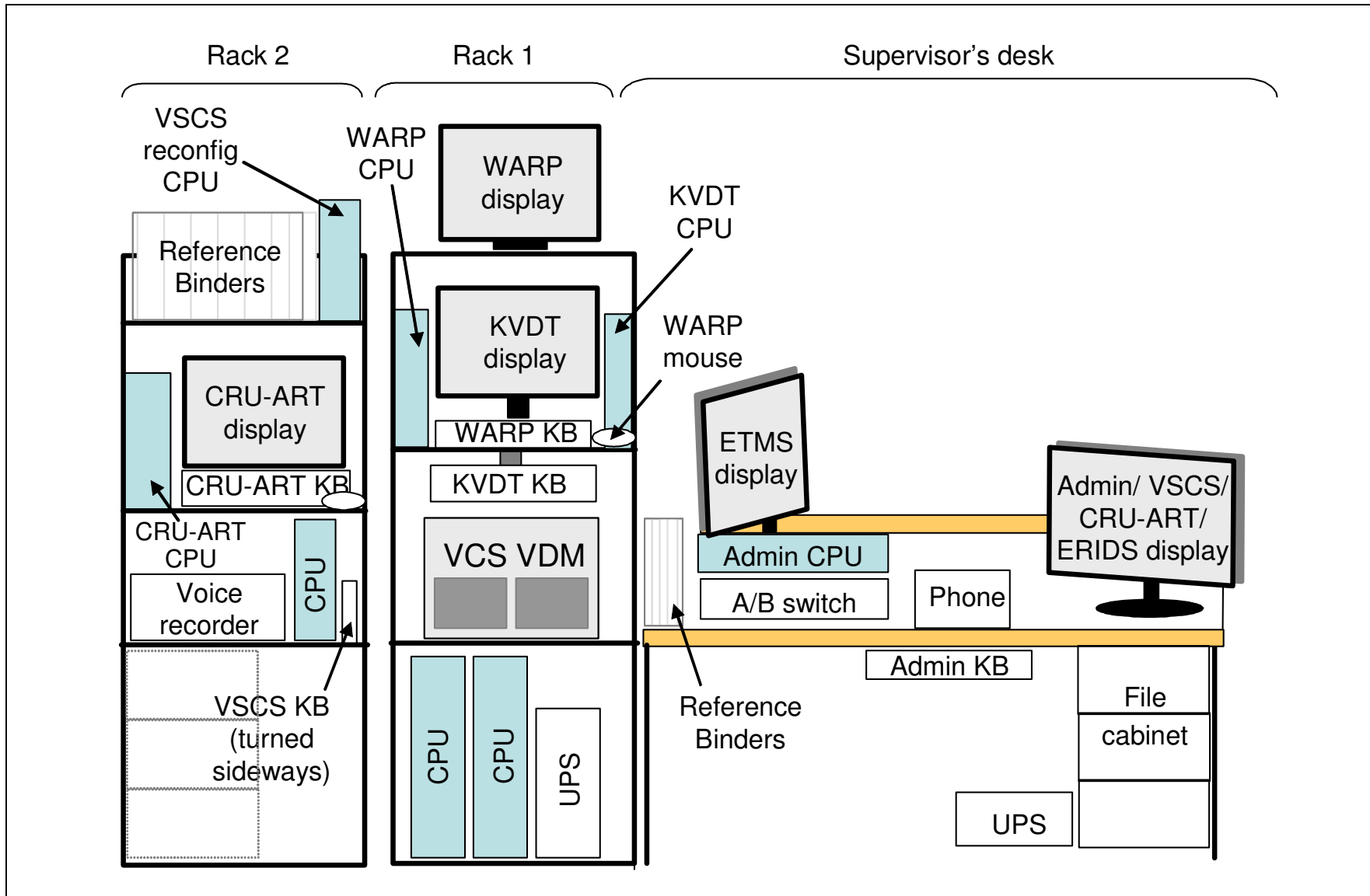


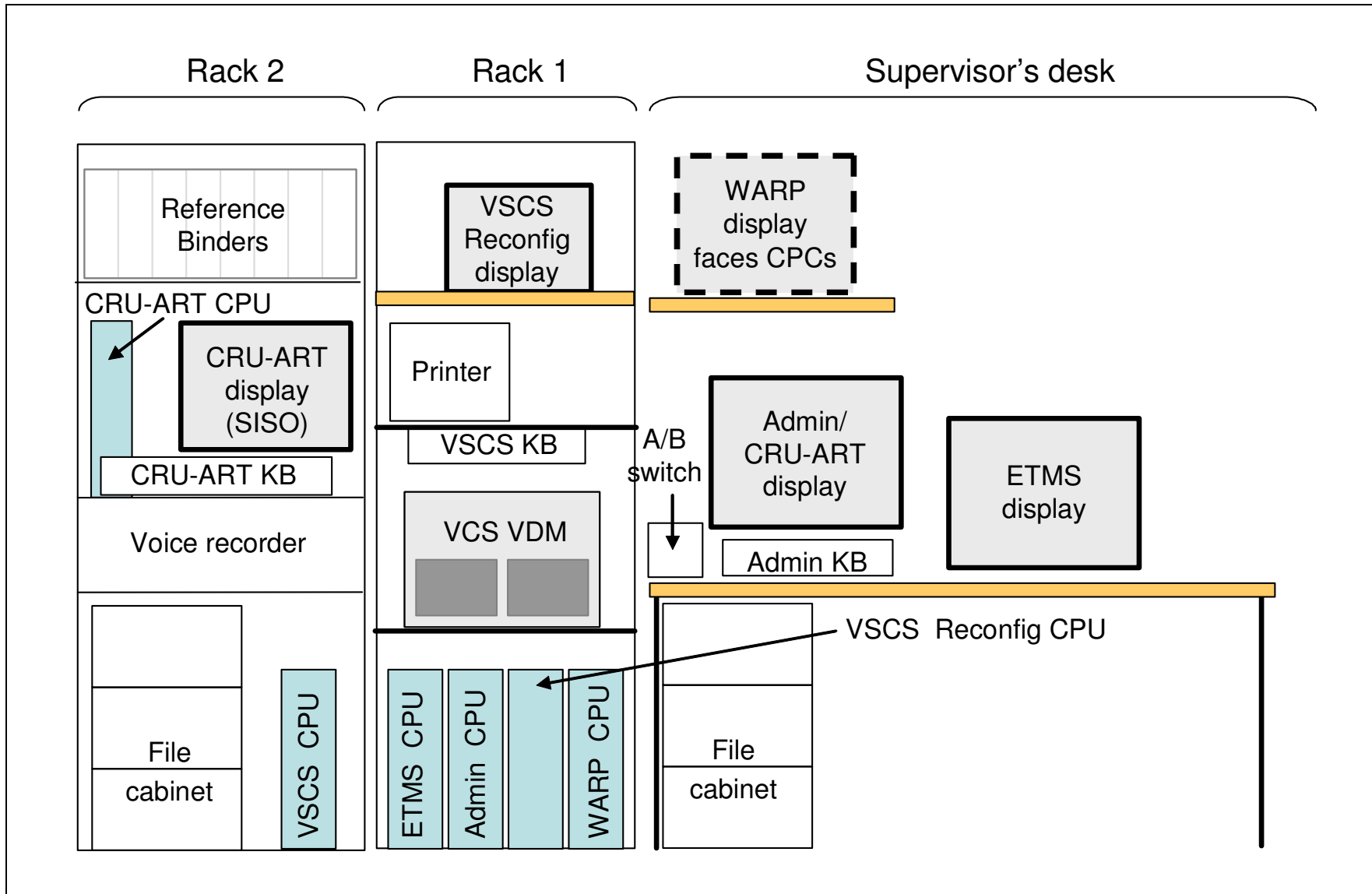


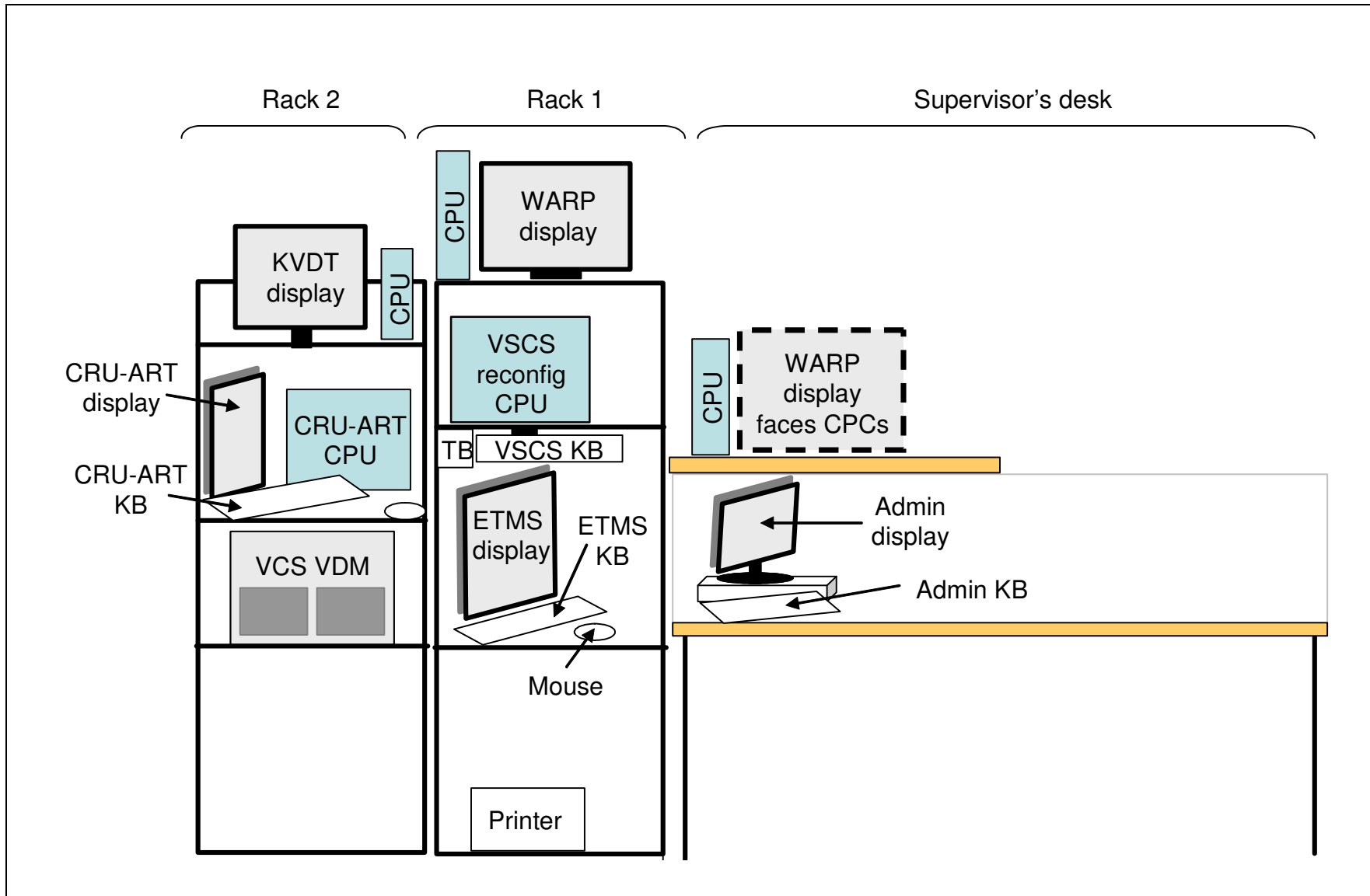


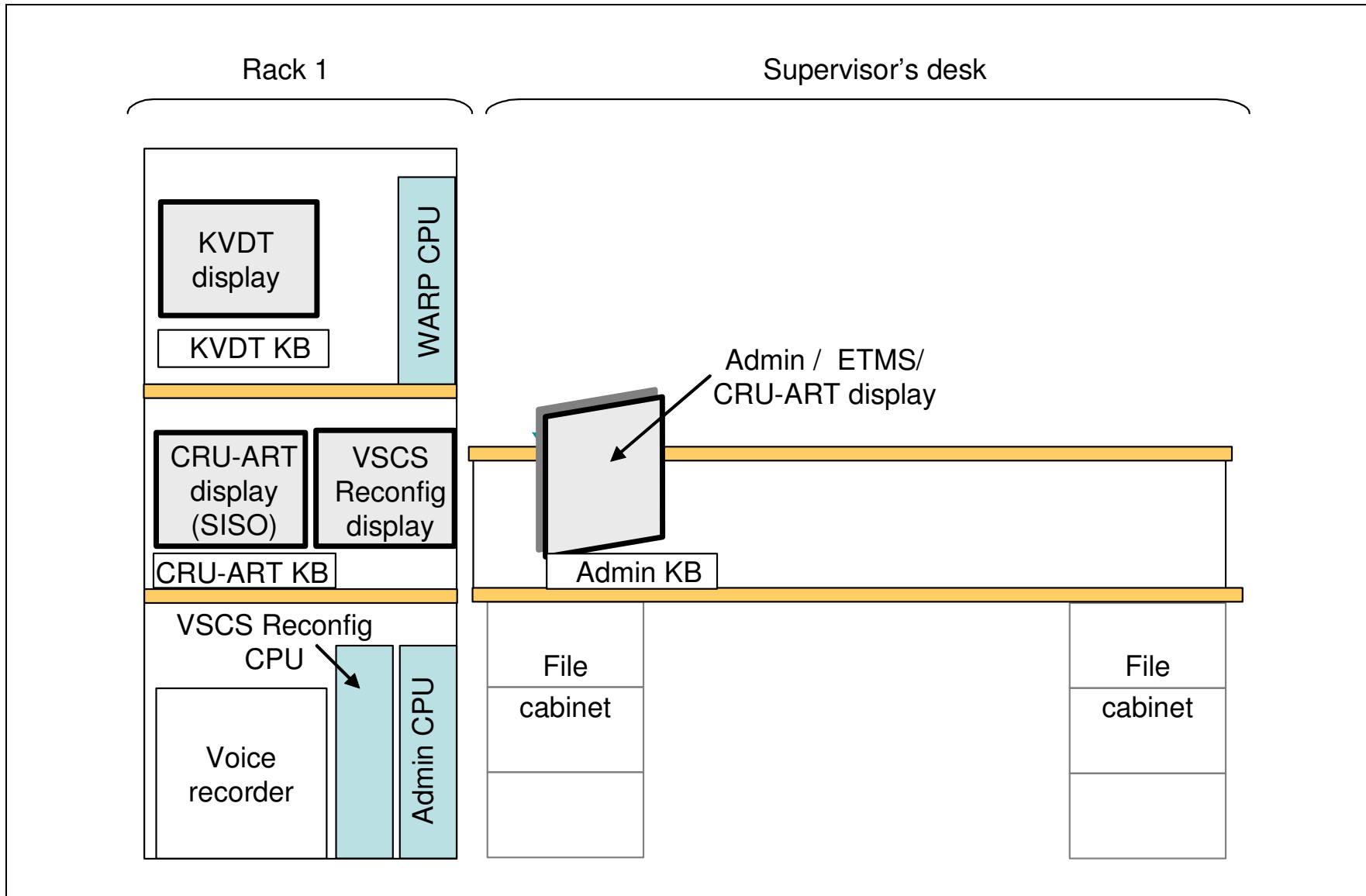
ZDV (Denver ARTCC)



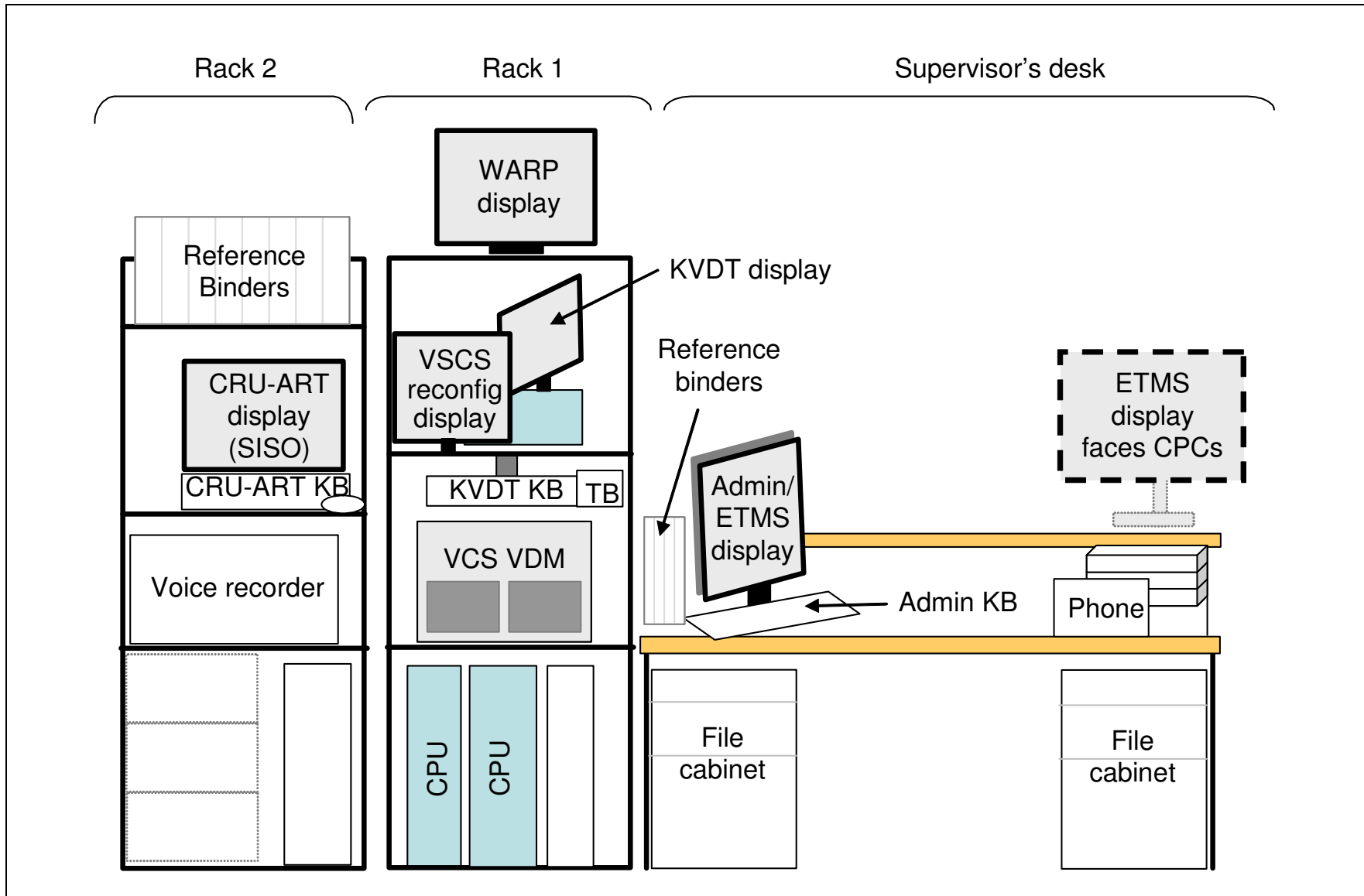


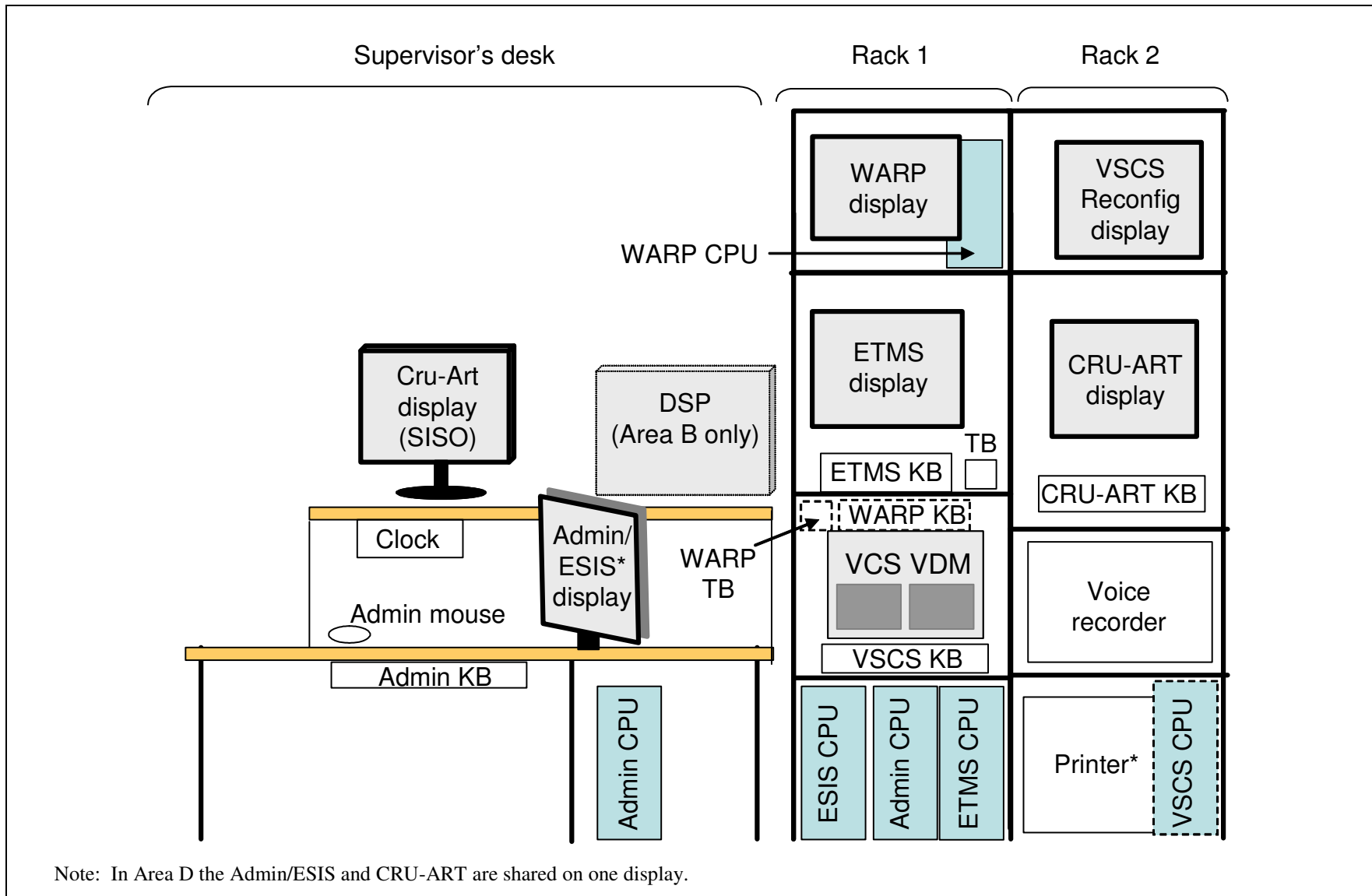


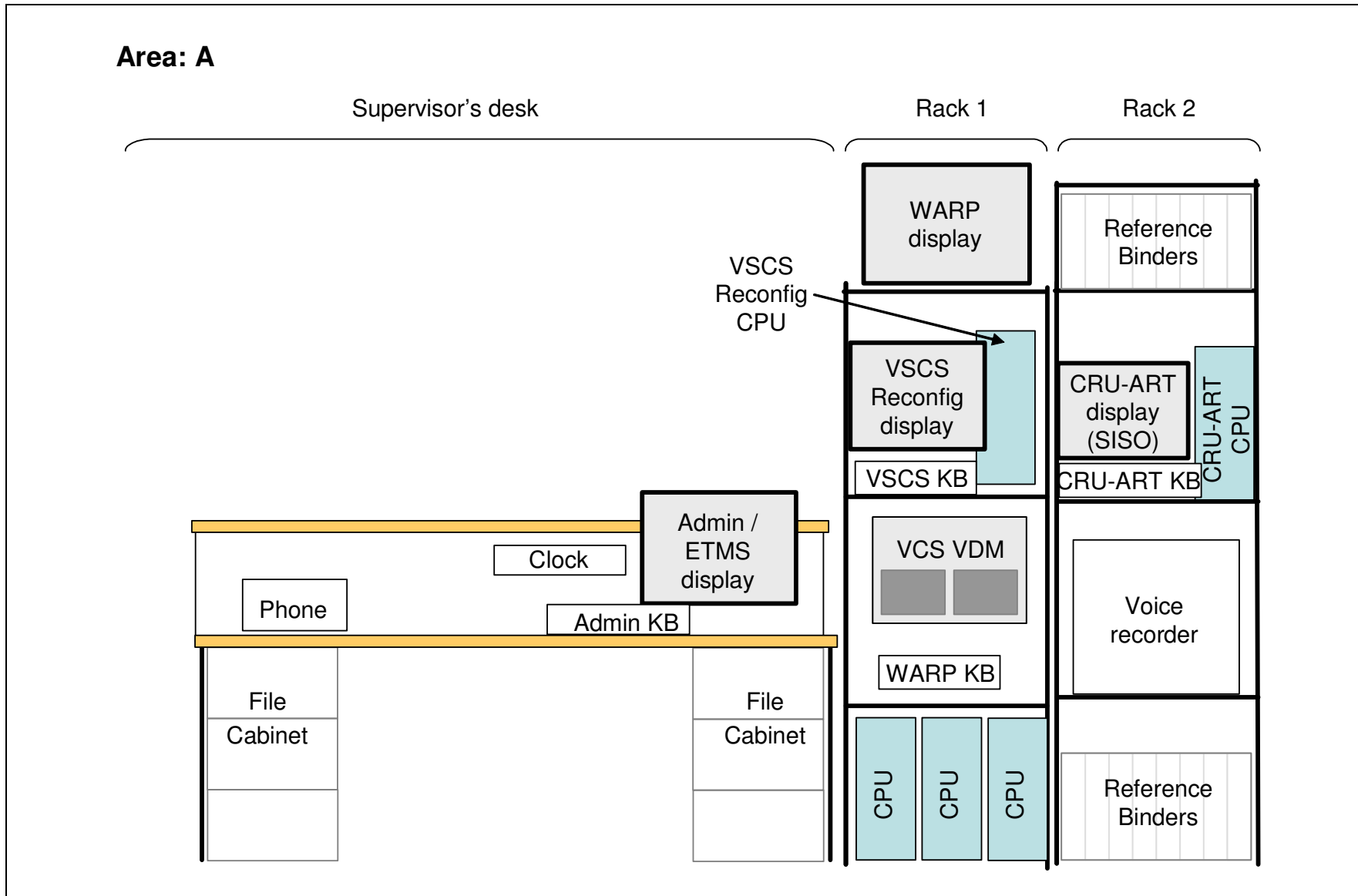


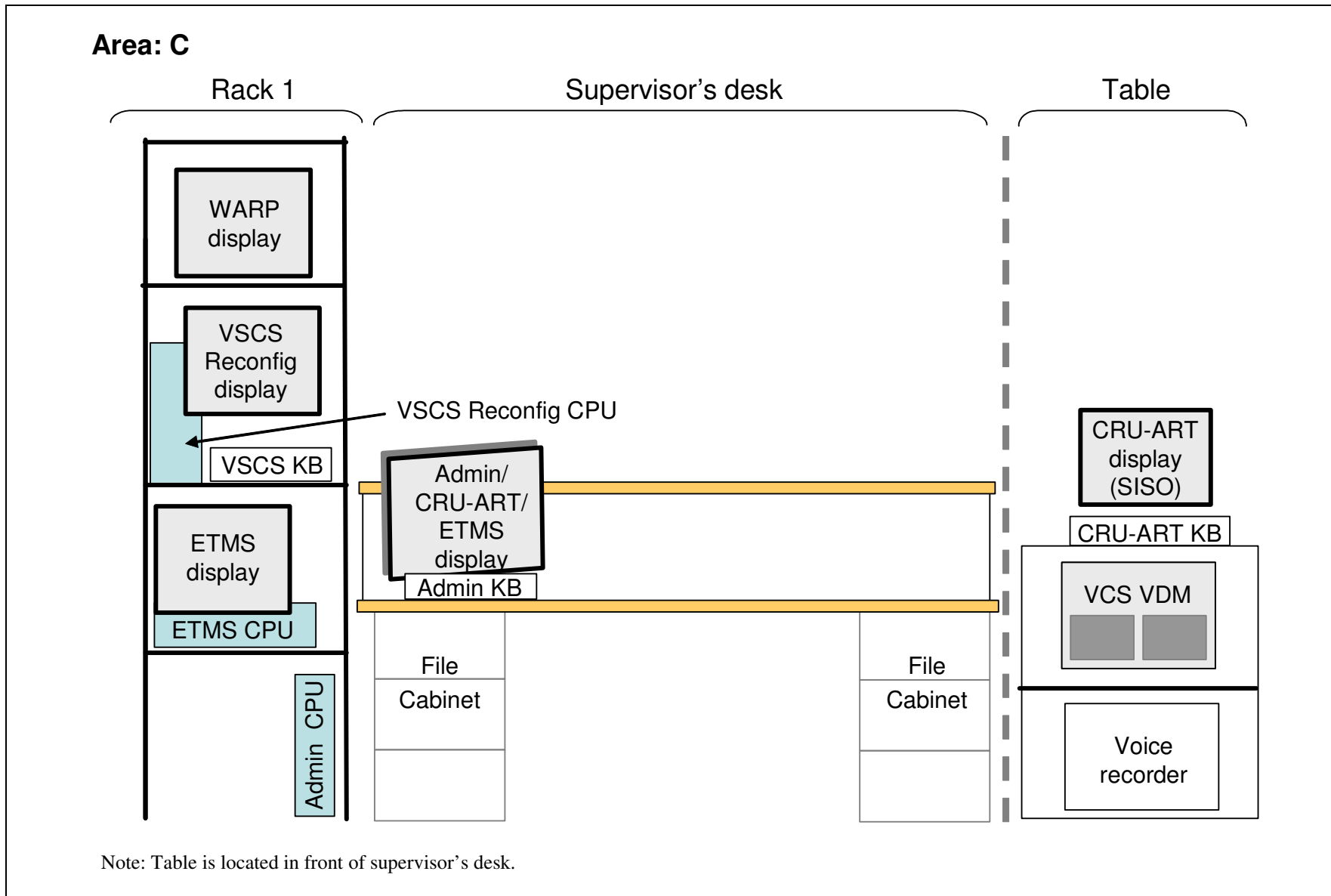


ZME (Memphis ARTCC)

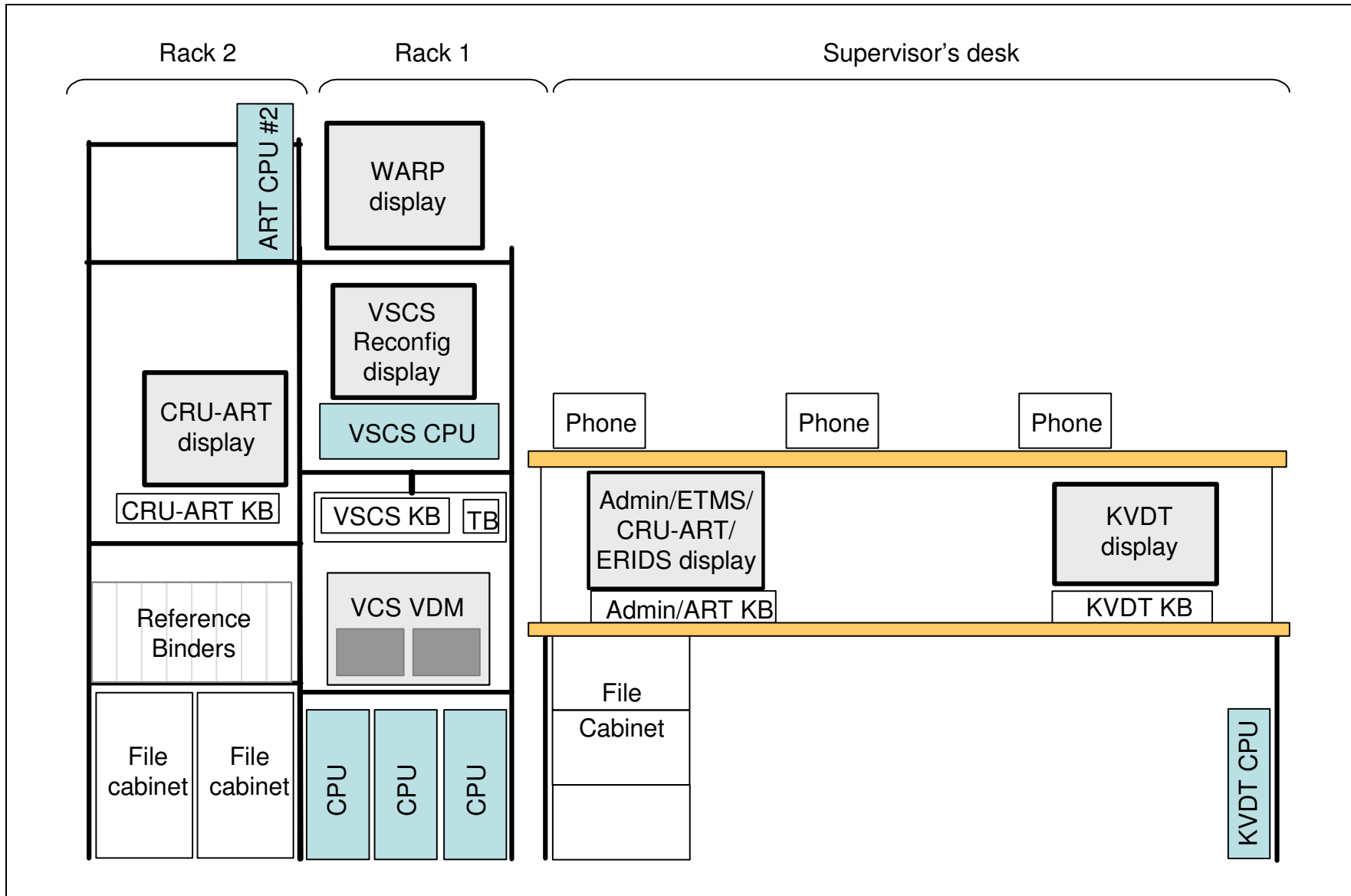






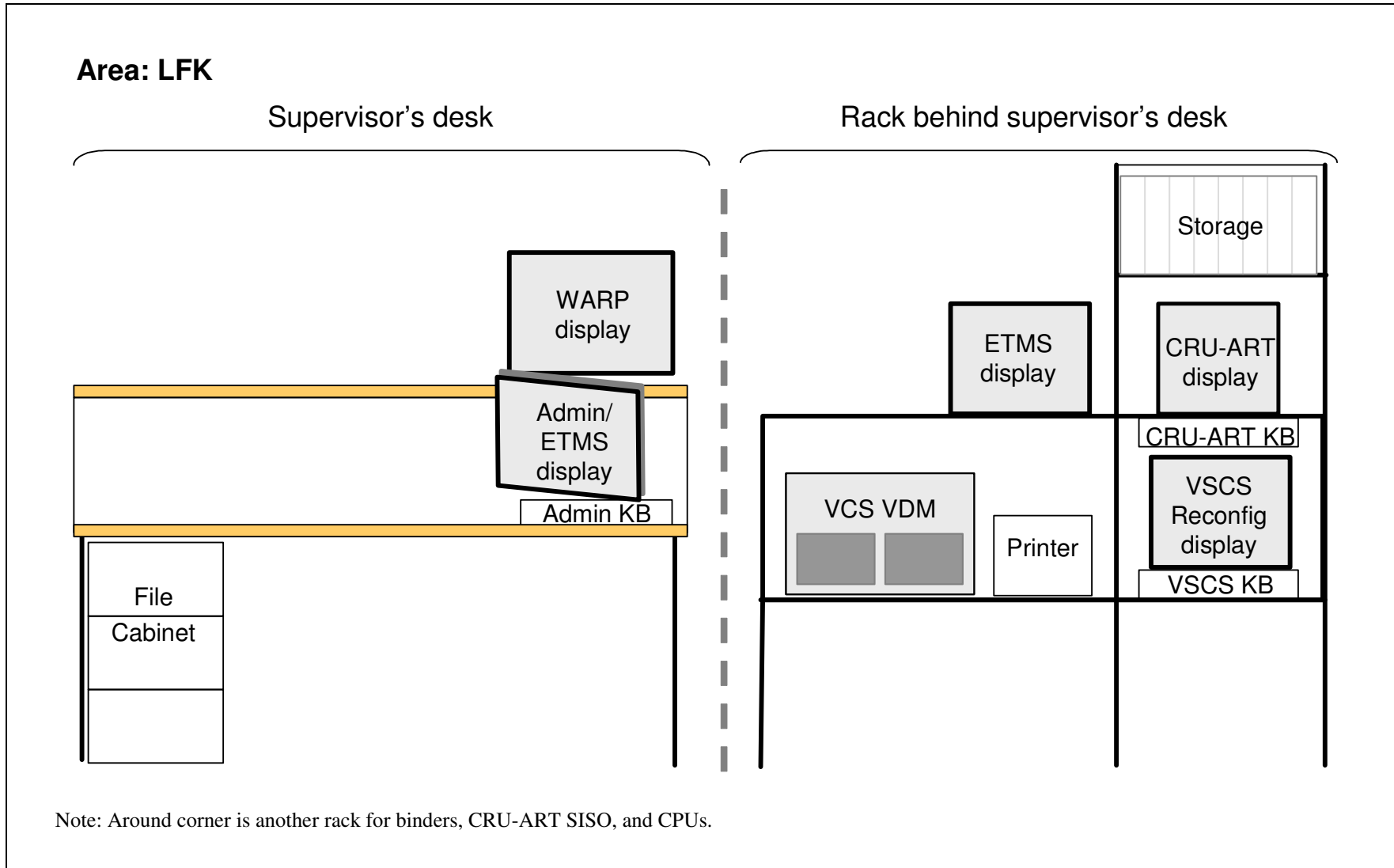


ZTL (Atlanta ARTCC)



Split (Supervisor parallel to DSRs)

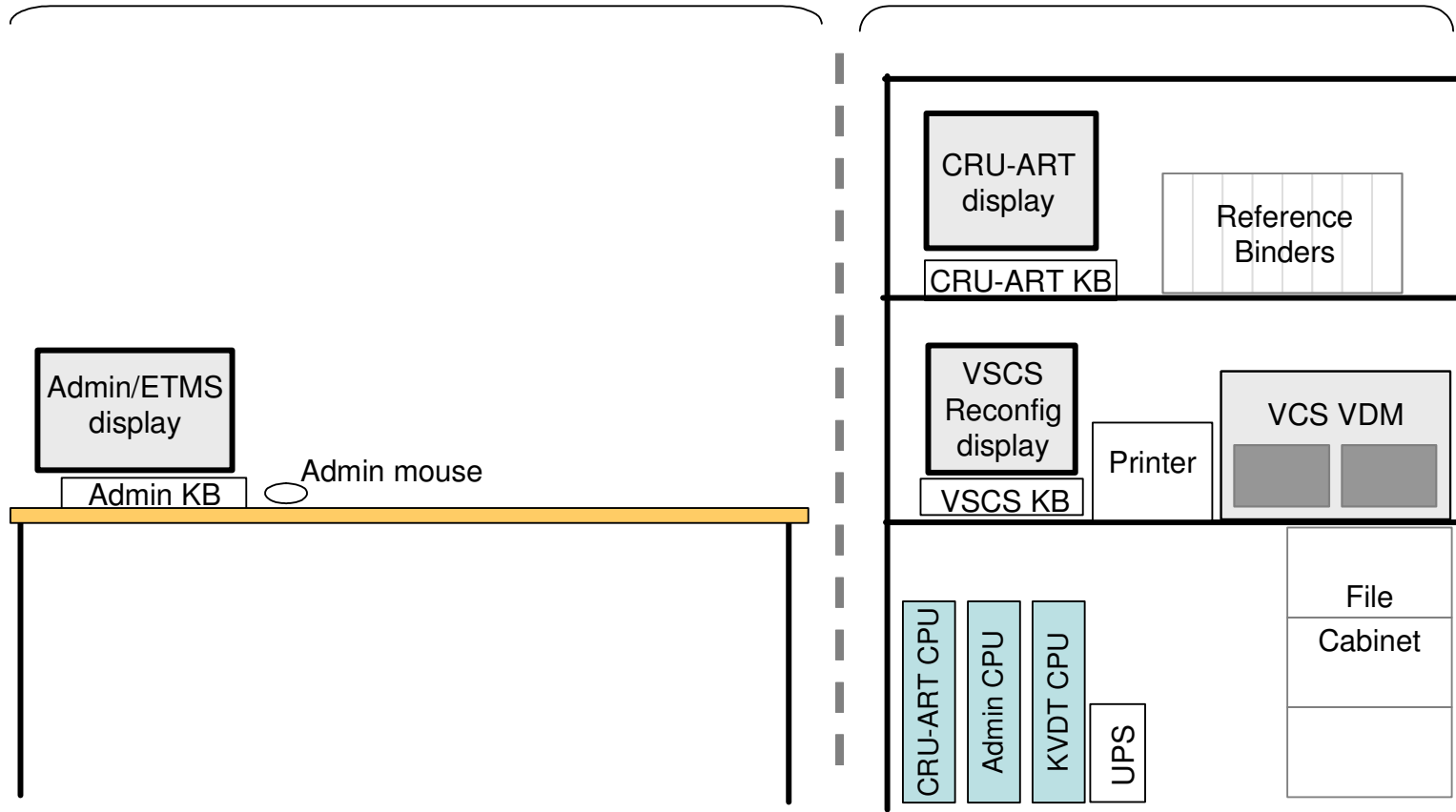
ZHU (Houston ARTCC)



Area: NEW

Supervisor's desk

Rack behind supervisor's desk



Note: Around the corner is a workstation for CRU-ART SISO. There is a separate table next to the desk for WARP.

