



**EVALUATING CONTINGENCY CONSTRUCTION METHODS: A DELPHI
STUDY**

THESIS

William E. Bentley, Major, USAF

AFIT-ENV-MS-18-M-177

**DEPARTMENT OF THE AIR FORCE
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THESIS

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EVALUATING CONTINGENCY CONSTRUCTION METHODS: A DELPHI STUDY

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Abstract

The purpose of this research was to evaluate which existing RED HORSE vertical construction system was “best” suited for contingency operations and the relative pros/cons/challenges associated with each. RED HORSE units, having existed for over 50 years, currently have 4 active duty squadrons currently employed overseas in multiple military contingency environments. Based on site visits, it was established that the Ultimate Building Machine (UBM)/K-Span, Professionally Engineered Buildings (PEB), and the FrameCAD system are the three most prevalent vertical construction systems/methods in use by RED HORSE. Fourteen Subject Matter Experts (SME) from across the Air Force participated in a Delphi study to evaluate these construction methods and answer multiple rounds of questions. While no one system/method could be conclusively declared “the best”, the Delphi study did generate consensus around the pros, cons, and challenges of each of these contingency construction methods/systems. The results of this study will serve to inform RED HORSE commanders/planner decisions regarding the use of vertical construction methods/systems for current and future contingency operations.

This thesis is dedicated to my wife and my son. They have always and will continue to support me in all my professional endeavors and journeys. Without them, I would not be the man or father I am today.

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William E. Bentley

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EVALUATING CONTINGENCY CONSTRUCTION METHODS: A DELPHI STUDY

I. INTRODUCTION

EXISTING contingency construction methods and assets employed by RED HORSE (Rapid Engineer Deployable Heavy Operational Repair Squadron, Engineer) were researched in this thesis using site visits and expert opinions responses through a Delphi Study. Chapter 1 introduces contingency construction and explains the methods RED HORSE currently uses for vertical construction (buildings). This chapter also states the research problem, which is what contingency construction method or asset is appropriate for each contingency environment the United States Air Force (USAF) operates in based on experts opinions. In addition to the research problem, the introduction discusses the rationale and justification behind this research, assumptions of this research, overall standards, and other support needed. Finally, chapter 1 discusses the methodology being used (Delphi Study) and why it is appropriate for this thesis.

1.1 Background

Within the 2016 Civil Engineer Flight Plan (CEFP), line of effort (LOE) 2.4 states that the USAF needs to “create lighter, leaner, and more resilient contingency equipment and installations” [10]. With a stated interest in creating more resilient contingency equipment, the USAF must look to our civilian partners for resilient and modern technology already being utilized and embraced across our country. Additionally, in the USAF’s Strategic Intent, the eighth objective is to “modernize capabilities while reducing operating costs”[11]. With the CEFP and the USAFs Strategic Intent both calling for modernization,

resiliency, and reduced costs, the Air Force needs to look into further utilizing end-to-end design and build systems in our many contingency environments.

Page 47 of the Air Force Strategic Master Plan discusses retaining full-spectrum capabilities. Specifically, “the USAF must continue to devise innovative ways to accomplish missions across the spectrum of conflict and “must not permit our focus on high-end conflict to cause the skills gained in low-intensity conflict to atrophy” [11]. Identifying, evaluating, and possibly modernizing the Air Forces construction assets is crucial to meeting the intent of the Air Force Strategic Master Plan. The Master Plan goes on to say “that the USAF will also consider investments in limited numbers of platforms, munitions, and off-the-shelf solutions optimized for lower-intensity situations when it is cost effective to do so” [11]. The use of “off the shelf,” end-to-end design build systems in contingency environments meets the intent of the Master Plan and this research will identify other existing construction systems that may be in need of investments and modernization [11].

1.1.1 RED HORSE History.

The Air Force has established multiple squadrons that currently conduct different levels of construction in contingency environments. RED HORSE, BEAR (Base Expeditionary Airfield Resources), Prime BEEF (Prime Base Engineer Emergency Force), and CRGs (Contingency Response Group) all currently have different levels of construction capabilities assigned to them that play a part in the Civil Engineer Supplement to the War and Mobilization Plan-1 2014 (WMP)[12]. Of the multiple squadrons and assets available for different levels of construction in contingency environments, only RED HORSE organically conducts semi-permanent or permanent construction.

The USAF currently has 4 active duty RED HORSE squadrons located at Nellis AFB, NV (820 RHS), Hurlburt Field, FL (823 RHS), Malmstrom AFB, MT (819 RHS), and Andersen AFB, Guam (554 RHS). Active duty is defined as full time military employment

versus Guard and Reserve military which are employed on some weekends or as needed by the state and federal governments. In addition to active duty RED HORSE squadrons, the USAF has recently bolstered the number of Air Force Reserve and Air National Guard units which are subsequently paired with one of the Active Duty squadrons for deployment rotation purposes.

RED HORSE was created in the mid-1960's when the former Secretary of Defense, Robert S. McNamara, sent a letter to the Air Force stating it:

“lacked the engineering capability to react quickly in emergency conditions such as: to provide bomb damage repair or other disaster recovery of installations when repairs were beyond base civil engineering's capabilities; to support tactical force deployments when such support may be required without declaration of a national emergency or war; and to provide “expeditionary” airfields and austere facilities in combat areas for tactical air force units” [13].

In response to this letter and the recognized need for the USAF to mimic existing Marine capabilities, RED HORSE was initially created out of existing USAF resources that were organized and trained at Cannon AFB, NM, before being sent to Vietnam to support the war efforts [13]. Soon, 2 RED HORSE units expanded within a year to another 4 RED HORSE units and all were employed in various locations across Southeast Asia to include Vietnam and Thailand [13].

As the Vietnam war slowed and eventually ended, the need for so many RED HORSE units also reduced. Over the course of the next few decades many units were deactivated or moved according to USAF construction needs. With the Global War on Terrorism beginning in 2001, RED HORSE once again saw consistent usage and had nearly nonstop deployments for RED HORSE engineers. Elements from each of the RED HORSE units deployed to Southwest Asia to support the operations and conducted many large scale horizontal and vertical construction projects [13]. To date, the USAF has one deployed

RED HORSE squadron, comprised of elements from all active, guard, and reserve RED HORSE units, rotating on a regular deployment basis.

1.1.2 Assumptions.

Although RED HORSE was originally created as a USAF asset to organically build military airfields, this thesis research will only focus on analyzing the existing RED HORSE construction assets used for vertical construction (buildings). RED HORSE has been in existence for over 50 years and its ability to use existing technology for contingency environments is paramount for continued agile mission support. In addition to only analyzing existing contingency construction assets, this thesis will not look into specific designs or structural specifications needed for contingency construction.

1.1.3 RED HORSE Contingency Construction Assets.

Based on site visits to both the 819th and 820th RED HORSE units, the Ultimate Building Machine (UBM), FrameCAD, and Pre-Engineered Buildings (PEB) are the three most common vertical construction methods and will form the basis of research for this study. At each of these site visits, RHS officers, structures Airmen, EA's, and other RHS personnel were informally interviewed and questioned about the most common construction methods and the direction of this research. The results of these site visits led toward the overall purpose of this research and the research questions developed afterwards. The site visits also allowed pictures and hands-on experience with the construction assets discussed below.

The UBM is a versatile and proven construction asset employed by RED HORSE units. UBM is defined as “the machine that makes buildings, is an all-terrain, factory on wheels that produces durable steel buildings in days rather than weeks or months” [14]. UBM's come in two sizes (120 or 240) which determines how large of a steel building can be produced [14]. Relatively small crews (10-12 personnel) are needed to assemble UBM

facilities (or K-Spans), which makes it a viable contingency construction asset for RED HORSE units [14].

Because FrameCAD is a relatively new RED HORSE asset, it is not currently Unit Type Code (UTC) classified by the USAF. This means that no specific training requirements are associated or mandated by the USAF for the FrameCAD software or hardware. FrameCAD was purchased in 2012 by both the 819 and 820 RED HORSE units as they saw a new asset that could fill many possible construction requirements. FrameCAD is described as an advanced, end-to-end design and build system enabling the rapid construction of quality buildings for businesses, governments' and communities worldwide [15]. It uses cold rolled steel formed into steel "2x4's" suitable for framing systems, roofing, flooring, walls and trusses [15].

When PEB construction is used by RED HORSE, it typically is a mixture of RED HORSE and contractor designs to complete the facility. PEBs vary in size and requirements when customers request them from RED HORSE construction. Additionally, minimal organic RED HORSE vertical construction assets are needed when PEB's are ordered and delivered. The few assets needed from RED HORSE would be used to setup and build the foundation. RED HORSE personnel will put together the facility based on the contractor provided designs and specifications.

RED HORSE units also employ "siding" machines which work well with the FrameCAD asset. These "siding" machines use aluminum or steel rolls to produce siding or roofing panels for metal facilities [6]. These machines can also be used for smaller facilities construction requested by RED HORSE customers. While the siding machines are often used in conjunction with FrameCAD they are not part of the FrameCAD system and will not be explored as an independent construction method as part of this study. Finally, while the 554th RHS does use tile-up construction techniques, it is the only one to do so. As a result, this methodology will not be considered any further.

1.2 Purpose of the Research

The purpose of this thesis is to evaluate which existing RED HORSE contingency construction methods are “best”, based on a panel of contingency construction experts, for contingency environments across the globe. Contingency construction experts are active duty Airmen, Reserve Airmen, Guard Airmen, retired, or separated Airmen that intimately worked with RHS vertical construction assets/methods for at least 1 year and have deployed a minimum of 1 time. The qualifications of the contingency construction experts will be further explored in the Methodology section. Additionally, this research develops a further understanding of available construction technology being used by the Air Force. Overall, the goal of this thesis is to provide a simple and usable tool that will allow Civil Engineers across the Air Force to quickly identify what contingency construction assets are available, what are there pros, cons, and challenges, and generally what types of facilities can be produced by them.

The following are the research questions addressed in this thesis:

- What is the “best” contingency construction method for vertical construction?
- What are the challenges of USAF’s contingency construction?
- What are the Pros & Cons of each vertical RED HORSE construction method?
- Is the USAF currently providing enough training for vertical contingency construction at RED HORSE units?
- Are other vertical contingency construction assets or methods needed to complete RED HORSE missions?

1.2.1 Materials and Equipment.

This thesis will provide verbiage that could update USCENTCOM’s “Sand Book” (deployment construction guide) and the War and Mobilization Plan to showcase the new

and current construction assets the Air Force has already procured or may need to procure. These updates will allow for all Civil Engineers to understand the contingency construction assets available when in a deployed or contingency environment.

1.2.2 Other Support.

With the support of an Air University provided research grant, visits to the Air Force Civil Engineer Center at Tyndall AFB, SILVER FLAG training site at Florida, 820 RED HORSE at Nellis AFB, and 819 RED HORSE at Malmstrom AFB were conducted. The support and interviews of the leadership and key personnel at each of these locations was invaluable in guiding this thesis research.

1.3 Methodology Overview

To evaluate the existing contingency construction assets employed by RED HORSE units, a Delphi study is used. A Delphi study is an iterative process of answering questions by soliciting opinions from groups (or experts) [16]. After each round, the responses are summarized and forwarded back to the experts for discussion in the next round. Ideally, the responses and analysis will provide the identification of common trends and ultimately a consensus may be reached by the experts [16]. The experts for this study were sourced from a variety of different RED HORSE units, Civil Engineer Squadrons, or private industry.

1.4 Summary

This chapter discussed the overall background of this thesis, including highlights from the AF Master Plan and the CEF, RED HORSE's general history, thesis research assumptions, and a brief explanation of current RED HORSE contingency construction assets. Additionally, the chapter defined the purpose of the research, the standards of contingency construction, other support provided from site visits, and the research questions. Finally, the Delphi methodology was briefly discussed and will be further explained in chapter 3.

The following chapter further explores each contingency RED HORSE construction method, their respective limitations, other construction methods, construction assets, and overall performance criteria for these methods and assets. Chapter 3, the Methodology, explains why using a Delphi method is relevant and justifiable. In Chapter 4, Results and Discussion, the Delphi method's experts' responses are analyzed and discussed. In Chapter 5, Conclusion, the consensus of the SME's is explained, additional research is proposed and a summary is presented for inclusion into Civil Engineer contingency planning documents.

II. LITERATURE REVIEW

2.1 Introduction

ONE military definition of contingency is “an emergency involving military forces caused by natural disasters, terrorists, subversives, or military operations” [17]. In addition, for this research’s purpose the definition of contingency is expanded to include humanitarian operations and remote location responses. Furthermore, this thesis defines contingency construction as military forces constructing vertical facilities (specifically PEBs, UBM, or FrameCAD) at natural disasters, terrorist events, subversive responses, military operations, humanitarian operations, or remote operations. By using this definition of contingency construction, this thesis includes all the different areas of operations of RED HORSE squadrons and further delves into each of RED HORSE’s vertical contingency construction methods.

As discussed in the previous chapter, the justification for this research is based upon statements in the Air Force Strategic Master Plan, the USAF’s Strategic Intent, and the Civil Engineer Flight Plan [10][11]. Based on these AF documents and plans, this thesis helps further the understanding of the different ways the AF currently conducts contingency construction. Following a general understanding of each contingency construction method or asset, a panel of contingency construction experts (using a Delphi study) will develop a consensus of each method’s performance. Finally, the panel of experts may possibly identify other contingency construction methods that may not currently exist in the USAF’s arsenal.

2.2 Contingency Construction Limitations

To better understand contingency construction, it is imperative to first understand the Air Force’s current definitions, limitations and policies. According to AFI 32-1032, “a

military construction project includes all construction and other work necessary to produce a complete and usable facility or a complete and usable improvement to an existing facility” [18]. Breaking this definition down further, military construction is defined simply “as any construction development, conversion, or extension of any kind carried out with the respect to a military installation, whether to satisfy temporary or permanent requirements, including acquisition of land” [18]. A project is “any maintenance, repair, construction, or combination of the three performed on or in a facility necessary to produce a complete and usable facility or improvement to a facility, regardless of dollar amount or execution strategy” [18]. In the Air Force Handbook (AFH) 10-222, contingency construction standards are discussed and the word “contingency” is considered for projects only from initial beddown to 2 years, then the term “enduring” would take effect [19].

Therefore, based on these multiple definitions, this research defines contingency construction as military forces constructing vertical facilities (specifically Pre-Engineered Buildings (PEB), Ultimate Building Machine (UBM) K-Span’s, or FrameCAD facilities) at natural disasters, terrorist events, subversive responses, military operations, humanitarian operations, or remote operations from bed down to base closure, site closure, or mission completion. This definition of military contingency construction reflects the Air Force definitions of a project, military construction, and military construction project; however, the Air Force’s definition does not include projects that are located off of military installations such as existing contingency environments. Additionally, using the word contingency as the Air Force Handbook describes, limits the time period that contingency construction projects could be constructed in and this research should actually focus more on enduring base development per AFH 10-222.

For most contingency construction projects (or minor construction projects), the fiscal limit is currently at 1 million dollars [18], which was raised from 750 thousand dollars in 2014. There may be the occasional MILCON (over 1 million dollar project) projects

that are considered contingency construction, but those projects will not be considered in this thesis [20]. Additionally, there have been other exceptions to contingency construction projects being funded only in the unspecified minor construction limit. RED HORSE has sought for these unspecified minor military construction funding limits on certain projects, which increases the project funding threshold to 3 million dollars [20].

2.3 Building Systems

Traditionally, building systems are considered the civil, mechanical, electrical, structural, or technology aspects of a project or facility. For this thesis, building systems are considered assets that can use a material (such as steel) to generate the structural components of a facility. Additionally, these systems could be considered a “factory on wheels” or a factory in a box [1]. Over the years, the USAF has purchased and employed multiple systems such as the Automatic Building Machine (also known as the ABM, and now retired), the Ultimate Building Machine (UBM), and the FrameCAD system. The USAF also relies on contractors to provide more specific buildings, such as PEB’s, when its organic building system assets, such as UBM or FrameCAD, do not meet project specifications and requirements. The following sections will discuss the similarities and differences between the UBM, FrameCAD, and PEB construction methods.

2.4 Contingency Construction Methods

2.4.1 Ultimate Building Machine.

The Ultimate Building Machine (UBM) is currently employed at all active duty RED HORSE sites and one is even available in the CENTCOM deployed environment. The UBM, according to the manufacturer MIC Industries, “the machine that makes buildings is an all-terrain, factory on wheels that produces durable steel buildings in days rather than weeks or months” [14]. The UBM currently comes in the 120 or 240 configuration, which both have specific limits to the width of the facility and gauge of steel used in the

machines. The 120 and 240 UBM's can be seen in Figures 2.1 and 2.2. In addition to different configurations, UBM facilities (K-Spans) also come in different types, such as 1, 2, or 3, which specifies the architectural look of each K-Span. MIC also states that a small crew of 10-12 individuals can manufacture and assemble a structure in a single day [14]; however, the manpower required for assembling K-span structures depends on how large the facility is and what additional facility requirements, such as HVAC, electrical, or plumbing, are being constructed. The training and equipment needed for a UBM project is also discussed below.



Figure 2.1: 120 UBM - Nellis AFB, NV

2.4.1.1 UBM Building Types.

K-Spans are typically viewed as Type 1, 2, or 3 (not to be confused with Fire Ratings of facilities). A type 1 K-span is a single arch facility which completely limits the bends during construction of the building and thus simplifies the overall construction of the facility. A type 1 K-Span can be seen in Figure 2.3. A type 2 K-span (also called a bread loaf) is similar to a type 1 K-Span, except it has straight walls below the single arch, which



Figure 2.2: 240 UBM - Nellis AFB, NV

maximizes the available floor space available. Although Type 2 K-Spans are possible, typically RED HORSE does not construct them [1]. Type 2 K-Spans are not typically built due to the difficulty of getting the UBM to produce the straight walls, a large arch, and then another straight wall. A type 2 K-Span can be seen in Figure 2.4. A type 3 K-span is different from both type 1 and 2 in that it has straight walls with three bends forming more of a traditional looking facility and it also maximizes floor space. A type 3 K-span can be seen in Figure 2.5 [2]. A Type 1 and Type 3 K-Span can be seen side by side in Figure 2.6. In addition to the Types of K-Spans, the configuration (either 120 or 240) has an effect on the size of the facility produced. A 240 K-Span can be seen in Figure 2.7. Dependent of the type or configuration, K-Spans vary from 12 feet to 120 feet wide, have a height between 18 feet to 40 feet, and the length can be unlimited [1].

2.4.1.2 Design Requirements.

Air Force EA's (Engineering Assistants) and engineers are needed to review each projects design and ensure the customer's needs and requirements are met. Additionally,



Figure 2.3: Type 1 K-Span - Yuma Proving Grounds, AZ [1]



Figure 2.4: Type 2 K-Span - Location Unknown [2]

MIC provides design reviews for each project and ensures the projects meet MIC and engineering standards. Once MIC has reviewed the project requirements, the EA's can incorporate the design into AutoCAD so that shops can review and edit the designs. AutoCAD is a software used to design and annotate engineer requirements for specific projects produced by the company Autodesk [21].



Figure 2.5: Type 3 K-Spans - Vandenberg AFB, CA [1]



Figure 2.6: Type 1 and 3 K-Spans - Nellis AFB, NV

2.4.1.3 UBM Manpower Requirements.

As stated earlier, MIC Industries touts that K-Spans can be constructed with crews as small as 10-12 individuals [14]. Although this may be true for just setting up the arches of the K-span, many different career fields of Airmen are needed to successfully construct



Figure 2.7: Type 1 240 K-Spans - Location Unknown [3]

a K-Span. Depending on the project requirements, not only are AF structures craftsmen needed, but also heavy equipment operators, HVAC technicians, electricians, plumbers, power production craftsmen, and equipment maintenance personnel. Although this is true for each of the systems being analyzed, this study only focuses on the unique system requirements. For larger scale K-Spans using the 240 UBM, additional personnel above the 10-12 individuals are needed for the facilities construction due to the weight and size of each span.

2.4.1.4 Equipment Requirements.

The amount of equipment needed for K-span facilities will slightly vary depending on whether it is a 120 or 240. The type of K-span, such as 1, 2, or 3, will not alter the equipment needed per construction effort. MIC industries also recommends a “construction support unit” and “coil transporter” to accompany the UBM [14], which each of the RED HORSE squadrons have purchased and made use of. The “Construction Support Unit”

(CSU) is a self-contained comprehensive workshop and tool storage trailer which also increases on-site construction capabilities with its ability to keep tools organized and to prevent theft with secure locks [14]. The 820 RHS's CSU can be seen in Figure 2.8. The “Coil Transporter” is a rugged coil transport systems that streamlines construction by feeding multiple galvanized steel coils directly into the UBM, along with supporting several additional coils of steel which can be loaded or replaced while operating the UBM [14]. The 820 RHS's coil transporter can be seen in Figure 2.9.



Figure 2.8: Construction Support Unit - Nellis AFB, NV

In addition to the CSU and coil transporter, many other pieces of equipment are needed to construct a K-span. In a US Army Corps of Engineer report, “Evaluation of K-Span as a Rapidly Erect-able Lightweight Mobilization Structure”, the general equipment requirements are highlighted and can be seen in Table 2.1 [9].

The seamer is a very important piece of equipment in this list and literally seams each metal K-Span panel together during the construction process and it can be seen in Figure



Figure 2.9: Coil Transport Unit - Nellis AFB, NV

Table 2.1: Recommended Equipment for K-Span Construction [9]

Recommended Equipment for UBM/K-Span Construction				
System Equipment:	Heavy Equipment:	Tools:		Concrete Placement Equipment:
Roll-Forming Machine	Earth Moving Equipment (to Level Site)	Rebar Cutter	Shovel	Vibrator
Seamer	Post Hole Digger	Drill-Powered Screwdriver	Framing Square	Trowel
Concrete Forms	Nalift or Cherry Picker	Heavy-Duty Cut-Off Saw (Chop Saw)	Ladder (20 ft adjustable)	Edger
Spreader/Lift Bar	Portable Welder w/ Generator	100-ft Tape Measure	Pry Bar (Large)	Cement Bugger
Vise Grip C-Clamps	Oxygen/Acetylene Cutting Torch	25-ft Tape Measure	Carpenter's Hammer (1 lb)	
	Crane (5-Ton capacity or greater)	Vice Grip	3-lb Hammer	
	Generator or Power Source for Power Tools	100-ft Extension Cord	10-lb Hammer	
		Transit	3/8 in Socket Set	
		4-Ft level	1/2 in Socket Set	
		Caulking Gun	3/8 in to 1-1/4 in Combination Wrench Set	
			Screwdriver Set	

2.10. Although this equipment list is provided in Table 2.1 [9], it is not all inclusive. The project location, the UBM configuration, additional project specifications, or the project team may dictate additional or other equipment not entailed in this analysis.



Figure 2.10: K-Span Panel Seamers - Nellis AFB, NV

2.4.1.5 Materials.

The main materials for all K-span facilities are steel and concrete. Without steel and concrete availability, K-spans are not possible. The configuration of the UBM, either 120 or 240, determines what thickness and specifications of steel are needed. An example of a steel coil is shown in Figure 2.11.

Additional materials besides just steel and concrete are also needed for a fully functional K-Span. Some facilities may require roll-up doors, personnel doors, HVAC, electrical outlets, lighting, insulation (either Pin-Weld or Spray-in), or special concrete coatings. It is necessary to know what all could be included in a K-Span facility, however, this analysis will not be considering any of these factors into the Delphi study. A K-Span that includes all of the materials mentioned in this paragraph can be seen in Figure 2.3 [1].



Figure 2.11: Steel Coils - Nellis AFB, NV

2.4.1.6 Training Overview.

Both the UBM 120 and 240 need annual calibration, and Airmen are required and provided annual training on both of these systems. MIC offers training at their headquarters (Reston, VA) which RHS typically sends its Structures Airmen to each year. MIC will also come to each RHS unit to do annual maintenance on the machines and conduct training as needed or required. Additionally, RHS structures craftsmen will conduct internal training throughout the year to build mini-k-spans in order to stay proficient on the UBM.

2.4.1.7 Logistics.

UBM's can be towed via tractor/trailers, which makes it a very mobile asset. No cranes or special equipment are needed to move the UBM's from location to location. UBM also meets Aircraft mobility requirements and can be flown anywhere in the world. MIC, however, is the sole provider of UBM technology, which limits its global support network [14].

2.4.1.8 Costs Overview.

Each UBM facility is typically budgeted for less than 1 million dollars when using troop construction or RED HORSE. Maj Sundry highlighted in a Talking Paper that UBM facilities are typically 40-60 percent less in costs than other facilities [1]. At a project at Yuma Proving Grounds (YPG), AZ, the 819 RHS constructed 3 K-Spans for 1.4 million dollars, each being well under the 1 million dollar threshold [4]. Two of the YPG completed K-Spans can be seen in Figure 2.12.

K-Span's cost are also dependent on customer and project requirements. The K-Spans built at YPG included roll up doors, personnel doors, HVAC systems, lighting, insulation, electrical outlets, and epoxy coated floors [4]. Each of these K-Spans at YPG were needed for the Military Free Fall School's parachute operations, and thus needed a climate controlled storage area. Many customer's may just need a storage space which would cause the overall costs of K-Spans to be reduced. Overall, the costs of K-Spans are relatively cheap depending on what the project and customer requirements are.

2.4.1.9 UBM Summary.

Overall, the UBM provides a simple, mobile, minimal material construction system and asset to RED HORSE Engineers. Based on the current system review, UBM is a viable contingency construction method currently in use by RED HORSE. A summary of the the UBM's building types, design requirements, manpower requirements, equipment requirements, materials, training, logistics, and costs can be seen below in Table 2.2.

2.4.2 FrameCAD.

FrameCAD is a relatively new acquisition for RED HORSE and the USAF, and both the 819 and 820 RHS are currently known to own this construction asset. As this is such a new acquisition, it is imperative to understand what kind of facilities it can produce, what are the general design requirements, what manpower is needed, what type of equipment is



Figure 2.12: Yuma Proving Grounds K-Spans - YPG, AZ [4]

Table 2.2: UBM/K-Span Summary Table

Ultimate Building Machine (K-Spans)	
Building Types	Based on Machine - Either 120 or 240. Also 3 standard design templates - Type 1, 2, or 3.
Design Requirements	Combination of EA's/Officers and MIC design support.
Manpower	~10-12 personnel for 120 UBM. Increased numbers for 240 UBM facilities. Also project requirements dependent.
Equipment	120/240 UBM, Crane, See Example List in 2.4.1.4.
Materials	Minimum of Rolled Steel, Concrete, and Rebar. Could include HVAC, Insulation, Electrical, Lighting, Roll-up Doors, Personnel Doors, etc.
Training	Either local or at MIC headquarters. Annual necessity and/or completing UBM facilities/projects.
Logistics	No special equipment needed for mobility. Can be towed. Air/Land/Sea capable.
Costs	40-60% less than other facilities. Full 120 UBM facility less than \$1M.

needed, what the annual training needs are, what kind of logistics does it entail, and how do the costs compare to other facilities. The FrameCAD machine container and insides can be seen in Figures 2.13 and 2.14.



Figure 2.13: FrameCAD Container - Nellis AFB, NV

2.4.2.1 FrameCAD Facilities.

Similar to the UBM, FrameCAD can build multiple types of facilities. The USAF has only begun to test the FrameCAD's possibilities with a few projects. As can be seen in Figures 2.15, 2.16, and 2.17, the FrameCAD was used to build 2 facilities at a site in Ft. Bragg, NC, for the John F. Kennedy Special Warfare Center [5]. FrameCAD facilities closely resemble PEBs, as will be seen below in the PEB section; however, FrameCAD is all built, assembled, and constructed on-site.



Figure 2.14: FrameCAD Inside - Nellis AFB, NV



Figure 2.15: FrameCAD Facility Sheeting Process - Ft. Bragg, NC [5]

2.4.2.2 Design Requirements.

EAs must have extensive FrameCAD software training, but the design requirements are organic to just RHS, and do not rely on any contractors or third parties. Unfortunately,



Figure 2.16: FrameCAD Facility Interior - Ft. Bragg, NC [5]



Figure 2.17: FrameCAD Facility Top View - Ft. Bragg, NC [5]

FrameCAD's design software does not currently work well with the EA's primary software AutoCAD [22]. This means that the EA's must redesign each facility again in AutoCAD due to the incompatibilities of the software.

2.4.2.3 Manpower Requirements.

Manpower solely depends on the facility size, but is similar to K-Span as FrameCAD is a very manpower driven construction method. MSgt Joseph Greene, a structures Senior Non-Commissioned Officer, states that “the machine requires two machine operators and one equipment operator (for steel loading procedures), and an assembly crew (4-8 personnel depending on scope and speed)” [22]. Different from the UBM method, less large/heavy construction members are being raised in the air during the construction process, except for roof joists/spans, and the ceiling framework. Most pieces constructed by the FrameCAD machine can be hand assembled and placed similar to wood construction. No specialty manpower is needed for most of the actual FrameCAD facility assembly.

2.4.2.4 Equipment Requirements.

The FrameCAD method requires many pieces of equipment, depending on the size and requirements of the facility. RHS typically owns cranes and large construction equipment that can construct FrameCAD facilities. One unique piece of equipment needed to move the actual FrameCAD conex is a “T-Rex” or a large crane. A “T-Rex” is a large piece of equipment specifically used to move containers (or conex’s). Due to the current size of the actual FrameCAD system, a 40’ container, as seen in Figure 2.13, makes it more challenging to move. The current size also makes it a logistics challenge, as this will be discussed further in the Logistics section.

In order for a FrameCAD to be fully usable, it is ideal to have the NTM roof/siding panel machine, which will be discussed in its own section. This machine can enclose FrameCAD facilities with aluminum or steel exterior walls and it can also construct the roof panels needed.

2.4.2.5 Materials.

The internal materials of a FrameCAD facility are dependent on the facility, the location of the project, and the requirements of the customer. However, the main

component of a FrameCAD facility are rolls of steel (very similar to a UBM facility). Similar to K-spans, concrete is also a critical component of the facility. The entire concrete pad must be prepped and poured before any of the FrameCAD steel members are set in place. Once the FrameCAD members are all assembled, plywood sheeting is needed to secure and enclose the facility. Lastly, the siding machine and its corresponding aluminum (or steel) rolls are needed for the roof and wall sheeting of a FrameCAD facility. This entire process and the materials mentioned can be seen in Figures 2.15, 2.16, 2.17, and 2.18 as a team of craftsmen from the 819 RHS constructed 2 FrameCAD facilities at Ft. Bragg, NC [5]. Additional other materials may be needed such as electrical wiring, lights, doors, roll-up doors, drywall, paints, HVAC, insulation, floor coatings, plumbing, plumbing fixtures, or other materials planned for the specific facility.

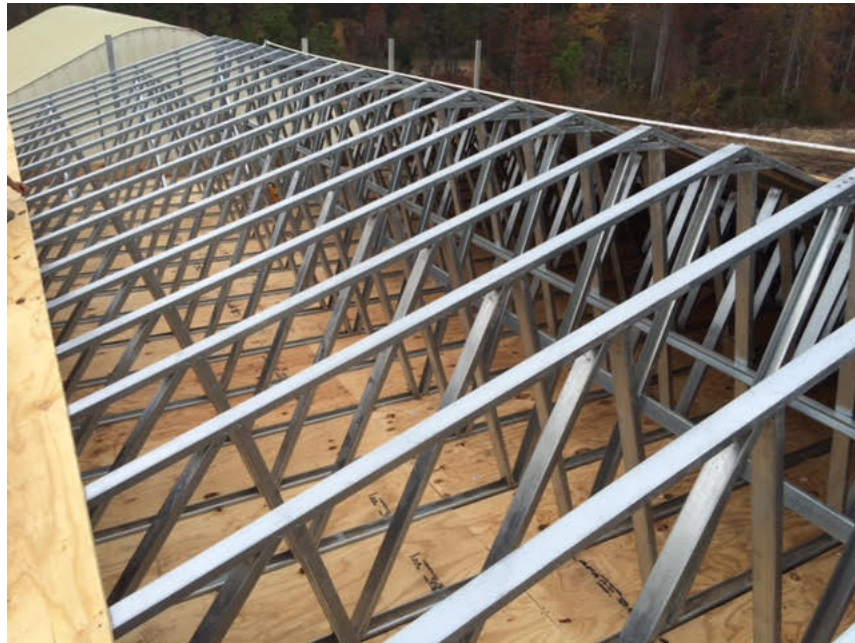


Figure 2.18: FrameCAD Roofing by 819 RHS - Ft. Bragg, NC [5]

2.4.2.6 Training Overview.

FrameCAD requires many specific training classes and knowledge gained through using it. Getting this training is a difficult pre-requisite for EAs and officers that are completing these projects. MSgt Greene also mentions that he is currently unaware or able to find a formal stateside training course for the FrameCAD as they are based out of NewZealand [22]. However, FrameCAD's website does identify 5 companies that are located in North America who may conduct training for military personnel [15]. Finally, because the FrameCAD is not an official USAF asset, training funding may not be a priority or allocated for either of the RED HORSE units that currently own it.

2.4.2.7 Logistics.

Due to the current size of the FrameCAD (located within a 40' container), moving and placing the FrameCAD can be cumbersome for RHS projects. As mentioned in the equipment section, A T-Rex or Crane is needed to load and unload the FrameCAD machine, which can be time-intensive and cost-prohibitive to RHS engineers. Other than moving the FrameCAD, FrameCAD's website has listed companies and individuals all over the world that are available for support [15]. This world-wide support listing is a great resource for using the FrameCAD in any contingency environment or getting any logistical support needed, although the FrameCAD has not been used overseas to date by the USAF.

2.4.2.8 Costs Overview.

FrameCAD facilities and projects constructed by RHS must be built for under 1 million dollars, similar to UBM and PEB projects. The Fort Bragg project built 2 FrameCAD facilities along with 2 K-Spans all for 1.7 million dollars as one project, but got approval for a Unspecified Minor MILCON project by the Army [5]. One of the FrameCAD facilities was budgeted for around 750 thousand dollars and the second being a smaller facility was budgeted for 250 thousand dollars [5].

Like other projects, an entire FrameCAD project depends on customer and project specific requirements. The larger FrameCAD facility at Fort Bragg included multiple restrooms, HVAC, lighting, multiple offices, plumbing, electrical outlets, and numerous other requirements. The smaller FrameCAD facility at Fort Bragg did not include restrooms and was planned for just office space, thus greatly reducing the costs.

Overall, costs of FrameCAD facilities may be very similar to UBM facilities due to steel being one of the main components needed. Additional projects will need to be completed so a more thorough analysis can be conducted comparing FrameCAD to both the UBM and PEB methods.

2.4.2.9 FrameCAD Summary.

Completed FrameCAD projects and facilities are very few in the USAF. There does appear to be some advantages to FrameCAD due to the unlimited possibility of different type facilities and minimal manpower needed to construct them. Minimal general materials, mainly rolled steel, being needed also would make it comparable to MIC's UBM. However, FrameCAD has some design challenges to overcome so that EAs don't have to do 2 sets of drawings [22]. Overall, FrameCAD seems very comparable to the other methods, but still must be evaluated and tested further to possibly be a usable contingency construction method. A visual summary evaluation of the FrameCAD system can be seen in Table 2.3.

2.4.3 Pre-Engineered Buildings.

Pre-Engineered buildings (PEB) are designed by a combination of RED HORSE engineers and contractors and the buildings' structural members are provided by contractors. Once the structural members are delivered by the contractor, the PEB is constructed by RED HORSE engineers. There is not currently an organic asset associated with PEB's, other than the FrameCAD mentioned earlier in the thesis. FrameCAD is

Table 2.3: FrameCAD System Summary

FrameCAD	
Building Types	Dependent on customer requirements. 1+ stories possible with troop construction.
Design Requirements	Combination of EA's/Officers. No contractor support needed.
Manpower	Minimal manpower needed. Dependent on project requirements.
Equipment	FrameCAD machine, small crane or forklift for lifting trusses. Similar equipment needed compared to UBM. May also need siding machine for roofing and exterior walls.
Materials	Minimum of Rolled Steel, Concrete, and Rebar and could include HVAC, Insulation, Dry Wall, Electrical, Lighting, Roll-up Doors, Personnel Doors, Plumbing, etc.
Training	Either local or at FrameCAD contractors willing to provide. Annual necessity and/or completing FrameCAD facilities/projects.
Logistics	Need large crane or T-Rex to mobilize FrameCAD conex and load on 40' trailer.
Costs	Are dependent on project/customer requirements. Minimal USAF projects (to date) for references.

similar, but cannot achieve all the same building specifications or structural loads as do PEBs. Some PEBs constructed by RHS can be seen in Figures 2.19 and 2.20.



Figure 2.19: PEB Under Construction by 819 RHS - Malmstrom AFB, MT



Figure 2.20: PEB Facility - Malmstrom AFB, MT

2.4.3.1 PEB Facilities.

The PEB method can supply a variety of facility types, mostly dependent on customer, base, and project requirements. PEB's can have larger width spans, mezzanines, and account for more specialized requirements. PEB's may also be mostly metal facilities, but the exterior may have architectural features, such as brick or concrete masonry units (CMU).

2.4.3.2 Design Requirements.

PEB's require much less design support from RHS engineers, due to the contractor doing much of the building's design. However, RHS is still responsible for the foundation design once the building has been mostly been designed by the contractor. This provides much less of a burden on the RHS Engineering Assistants, and allows them to focus efforts on other critical parts of a project.

2.4.3.3 Manpower Requirements.

PEB's manpower would depend on the size of the facility and what the project details entailed. The manpower of a PEB is similar to both K-span's and FrameCAD facilities, as

all three methods/systems manpower truly depend on how specialized the facility is. The overall manpower required could entail all crafts (such as HVAC, plumbers, electricians, etc), or possibly only Structures Airmen and Heavy Equipment Operators. Additionally, the PEB's manpower would entirely depend on the contractor provided schematics and instructions, along with the specific project requirements.

2.4.3.4 Equipment Requirements.

PEB's require a combination of support equipment comparable to both the K-span and FrameCAD. PEB's do not, however, require an organic asset, such as the UBM or FrameCAD, to construct a facility. The PEB's construction members are built at a contractors facility, then packaged, and delivered directly to the project site for assembly. RED HORSE is responsible for providing the equipment necessary to assemble the entire facility which could entail cranes, forklifts, bulldozers, backhoes, dumptrucks, or other equipment necessary for each individual project.

2.4.3.5 Materials.

PEB's source materials through the contractor that wins the bid for the project. The ease of the PEB method is that the contractor that wins the project must procure and provide all the necessary materials to build the facility. RED HORSE does however typically design and build the foundation of the PEB, which includes concrete and rebar.

2.4.3.6 Training Overview.

PEBs require less annual training than FrameCAD and UBM due to it being more of an assembly than an actual organic RHS asset. Typical training for a PEB occurs when actually accomplishing a PEB project. The more PEB projects a RED HORSE unit has, the better trained RED HORSE personnel are for future PEB projects.

2.4.3.7 Logistics.

Less logistics are needed for PEB's as the contractor designing/building the PEB is responsible for delivering the PEB to the construction site. This is also true in overseas

environments, which could be considered an advantage to PEB's versus the UBM and FrameCAD methods. The key to PEB's logistics is having the time to design, contract, order, build, and ship the actual PEB to the construction site.

2.4.3.8 Costs Overview.

PEB costs can vary greatly depending on the size of the facility ordered and needed by the customer. PEB's typically cost more than a UBM due to the need for contractor designs and manufacturing. In addition, the contractor must deliver the facility to the project location in order for RHS craftsmen to complete the project. The same rules apply for the acquisition of a PEB facility as the other construction methods/assets and the project must be kept under 1 million dollars unless other funding approvals are sought out.

2.4.3.9 PEB Summary.

PEB's provide customers specialized facilities and have similar manpower and equipment requirements as the FrameCAD and UBM methods/assets. The costs are typically greater due to the specialized nature and requirements from customers and the reliance on contractors for the design and material procurements. An overall visual summary of the PEB method can be seen in Table 2.4.

Table 2.4: PEB Method Summary

Pre-Engineered Buildings	
Building Types	Any building type possible.
Design Requirements	Combination of EA's/Officers (foundation) and contractor design support.
Manpower	Dependent on size of facility requested.
Equipment	Crane, Forklift, Scissor Lift, and/or contractor required equipment per project requirements.
Materials	Contractor provided. Concrete/Rebar needed for foundation/columns support.
Training	Completed through projects.
Logistics	Minimal logistics requirements. Dependent on contractor for delivery.
Costs	Dependent on project. Can be less than \$1M using troop labor.

2.4.4 Siding Machine Overview.

The siding machine is paired with FrameCAD or PEBs in order to provide walls and/or roofing members as needed. This is an organic asset to RHS and can be easily moved and transported to different locations. It uses rolled aluminum or steel, similar to the UBM or FrameCAD using rolled steel. The 820 RHS's siding machine can be seen in Figure 2.21. A more detailed picture of the siding machine can be seen in Figure 2.22 [6].



Figure 2.21: 820 RHS Siding Machine

2.5 Other Construction Methods

This section contains a brief overview of other construction techniques or assets employed in civilian or other military units. Because they are less common for contingency operations and are not fully employed by RED HORSE, they were not explored further in this research.



Figure 2.22: NTM Siding Machine [6]

2.5.1 Howick FRAMA Mobile Factory System.

Howick's FRAMA system is almost identical to the FrameCAD system. Howick is based out of New Zealand and has been around since 1978 [7]. Howick also mentions a few benefits to using their system such as: no license or toll rolling fees, world leading software links, all machinery is CE and UL compliant, open language interface, and choice of software [7]. As can be seen in Figure 2.23, the Howick's FRAMA system looks very similar to the FrameCAD purchased by the 819 and 820 RHS seen in Figure 2.13.

2.5.2 Tilt Up Concrete Construction.

The 554 RHS currently uses this construction method to build most of its facilities on the island of Guam. It is also extremely common in industry. The concrete is poured and tied while on the ground, then lifted into place and secured. Large cranes are needed to lift the concrete slabs into place while the construction crews ensure they are secured together. This construction method may have many benefits if it were used more in specific contingency environments (such as the additional strength needed for facilities with specific anti-terrorism/force protection standards).



Figure 2.23: Howick's FRAMA Mobile Factory [7]

2.5.3 Plastic Frame Concrete Construction.

Plastic frame concrete construction was discussed in Major (USAF) John Tryon's (now Colonel Tryon) thesis from 2005 and he described it as "an innovative construction technique, the erection of plastic finished formwork which is filled with reinforced concrete, could be a new way of performing vertical construction in deployed contingency environments" [23]. Maj Tryon also discussed Royal Building Systems (RBS), which is a "derivative of Royal Building Technologies, a Canadian plastics company that supports the construction industry world-wide with innovative plastic building solutions" [23]. Similarly, a website called "The Constructor" claims the "use of plastic formworks for concrete construction has many advantages such as durability, cost and flexibility compared to other materials for concrete formworks" [24]. Another company similar to RBS, Dscaff Group, says their "plastic formwork system is totally modular, and suitable for shuttering and forming columns, walls, beams and slabs, a comprehensive range of accessories allow you to solve most problems with minimal effort" [25].

2.5.4 Modular Building Systems.

Modular building systems are facilities that are already constructed (similar to a mobile home or travel trailer), but the foundation and utilities are needed before installing them. These building systems are currently being investigated by AFCEC. They may be very quick to setup, but are very costly to acquire due to the contractors designing, procuring, assembling, and delivering the facility. Although the costs may be high, these systems may be ideal for certain contingency environments where time is crucial and materials are limited for construction.

2.5.5 Wooden Construction.

Wooden construction is still a viable means of construction for both Civil Engineer units and RED HORSE. When on a site visit to the Silver Flag training ground near Tyndall Air Force Base, Florida, the research team discussed and saw wooden construction still being practiced. Civil Engineers have been known to build “B-huts,” “SEA huts,” and other wooden facilities in contingency environments. These facilities have also been built at the Silver Flag training site and are commonly known to the military services. Wooden construction will continue to be a primary means of providing facilities in any environment and Structures Airmen are taught this at their core training, however RED HORSE does not currently practice this technique as much as PRIME BEEF Structures Airmen. Additionally, this construction technique was not further explored in this research due to infrequent use and request of wooden construction projects, and they do not meet many of the USAF’s construction standards for new facilities.

2.6 RED HORSE Construction Assets

Both the UBM and FrameCAD are unique in that they are completely organic to the USAF and RED HORSE. Although the FrameCAD system has only recently been purchased by the USAF, it is not acknowledged as official equipment like the UBM. The PEB method completely depends on contractors to design, acquire, and construct the

facility structural members before RED HORSE engineers assemble it on the project site. Although the PEB method is not an actual asset of RED HORSE's, it is still a very common and reliable construction method used by all RED HORSE units.

2.7 Performance Criteria of a System/Method

The performance criteria of these contingency construction systems/methods could have many different categories. As discussed in previous sections, the following categories were analyzed for each of the primary RED HORSE construction methods/system:

- Type of facilities that can be constructed
- Design requirements of each system/method
- Manpower needed to use each system/method
- Equipment requirements
- General materials needed
- Training needed
- Logistics overview
- Costs summary

The following categories will be used as the performance criteria in a contingency environment: size of facilities, speed of construction, and logistics support needed. These three criteria were chosen based on the operational experiences of the researcher. Each of these will be discussed in the following subsections.

2.7.1 Size of Facilities.

The sizes of the facilities produced by the UBM/K-span, FrameCAD, and through PEB construction all vary greatly. K-spans facility sizes would have to be the most

standard, as they have generally 3 designs, and 2 overall sizes. The key feature of K-spans is that their length could be almost endless, if a facility like that was desired. Both the FrameCAD and PEB construction methods have much more variation to facility sizes. FrameCAD's weakness would be the inability to produce facilities that have large width open-spans, which the PEB method would excel at or even the larger 240 K-span. If an office type facility is desired, the FrameCAD or PEB methods would be preferred. If a facility needs to be very specialized for a certain mission or need, the PEB method might be sought due to the professional engineer expertise that comes with it. Overall, the size of facilities would depend on the customer or project requirements, and each of these methods/systems must be individually evaluated on those basis in contingency environments to complete the missions requirements.

2.7.2 Speed of Construction.

The speed of construction using each of the discussed RED HORSE construction methods/assets could be critical in certain contingency construction situations. Each of these assets/methods evaluated so far all have different time-lines that must be understood by the engineer, customer, and project manager. The UBM is easily transportable, and if steel is on-hand, a entire facility's exterior could be accomplished in a day. Similar to the UBM, if the steel needed for a FrameCAD facility is on-hand, a whole facility's internal structure could be generated and constructed in a matter of days. Both the UBM and FrameCAD do require foundations to be established before the structural members are placed. PEB's, however, take much more time to order, build, deliver, and construct the facility than UBM or FrameCAD facilities. FrameCAD or UBM could be used to pre-build the structural members of a facility similar to the PEB method, and RED HORSE or Civil Engineer Airmen could then transport the structural members to the needed project site. Overall, the speed of each method/asset is very different and could be a critical decision factor in a contingency construction environment.

2.7.3 Logistics Support Needed.

The logistical support needed for each system/method varies greatly. This category is also directly related to the size of the facility and the speed of construction required. If the facility needs to be built extremely fast and no specific size requirements were requested, then possibly the FrameCAD or UBM assets would be advantageous. Other logistical concerns for each of these systems/methods are the location of the project, Airmen available for construction, equipment available, tools available, construction time-lines, size of the facility, cost of the project (or available budget), and/or customer requirements. If a very specialized facility is needed and the time-line is extensive, a PEB facility would be the ideal construction method. If the correct rolled steel is on-hand for the UBM or FrameCAD, each of the logistical burdens for these systems would be greatly reduced. Overall, the logistics support needed for each of the contingency construction systems/methods being evaluated would be specific to the environment and conditions of the project/facility requested.

2.7.4 Summary.

This literature and systems review discusses and overviews each of the systems/methods being employed by RED HORSE squadrons. The following topics were discussed based on the site visits to each RED HORSE unit by the researcher, systems analysis, and relative literature review:

- Facility types
- Design requirements
- Manpower requirements
- Equipment requirements
- Materials needed

- Training needed
- Logistics requirements
- Costs Overview

Other construction methods were also presented and briefly discussed. The performance criteria of these evaluated systems/methods was also discussed. Additionally, the research summarized each of the systems and provided a visual summary.

Based on this literature and systems/methods review, a Delphi study was designed, which is further discussed and explained in the Methodology chapter. After the Delphi method is explained in chapter 3, chapter 4 analyzes the data collected from the panel of contingency construction experts. The final chapter explains the findings, provides an overview on potential future research avenues, and concludes the overall goal and meaning of this research.

III. METHODOLOGY

3.1 Introduction

SEVERAL construction methods and assets were explored throughout the literature review. The trend is that while each of the contingency construction methods are not identical, each of them are linked by the size of the facilities, the speed of construction, and logistics support needed. The core foundations for each of these contingency construction methods has been established, but the interpretation of each of their performances in a contingency environment is still needed. A Delphi study was conducted to get contingency construction subject matter experts from various Civil Engineer and RED HORSE squadrons to provide various opinions and interpretations of how each contingency construction method performs. The experts were asked what is good or bad for each system/method, and are there any other methods the USAF may need to adopt. This chapter also explains the Delphi method's process, what defines a contingency construction expert, the limitations of the experts, and how this thesis will ask and analyze the questions of each Delphi round. The results and discussion analysis will be presented in chapter 4 and the summary and impacts of the research will be discussed further in chapter 5.

3.2 The Delphi Method

With the ambiguity of defining contingency construction in the governing documents of the Civil Engineer community, there is a lack of marketing and understanding of the USAF's organic construction methods available. A majority of the information exists only internal to each RED HORSE squadron. A Delphi study was used to gain a better understanding of construction methods based experiences of Civil Engineer and RED

HORSE construction experts. These contingency construction experts were invited from multiple squadrons and civilian agencies to ensure a diversity of opinions.

The Delphi technique was chosen because of its ability to forecast information and it “eliminates committee activity among the experts altogether and replaces it with a carefully designed program of sequential individual interrogations (questionnaires) interspersed with information and opinion feedback” [26]. Simpler said, the delphi method “solicits opinions from groups in an iterative process of answering questions” [16]. It is of note that the information provided in a Delphi study is the opinions, experiences, and interpretations from each of the subject matter experts. Each of the participants has experiences in constructing UBM, FrameCAD, and PEB facilities while deployed or at a RED HORSE unit. The analysis of each expert’s response and interpretation is subjective; however, other researchers could get similar results based on the analysis conducted and by using the Delphi method.

As can be seen in Figure 3.1 [8], the ideal plan for a Delphi method is to provide 3 rounds of questions, perform analysis and feedback after each round, and provide an overall conclusion after the third or final round. Similar to Figure 3.1, this thesis may conduct 3 rounds of questions with an overall analysis after each round and a conclusion after the final round, ideally resulting in a consensus from the experts.

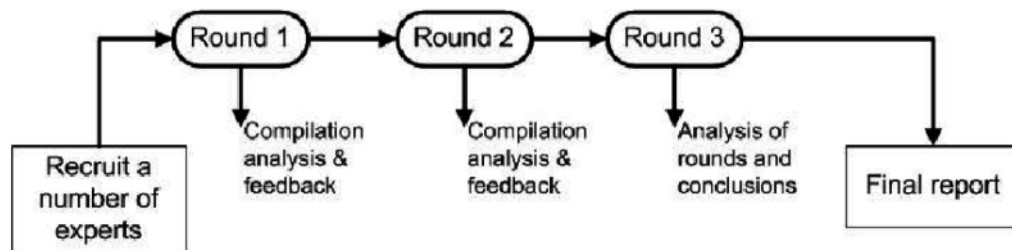


Figure 3.1: An Example Delphi Method [8]

3.3 The Participants

In order to provide enough diversity in the responses, multiple participants were sought out among Civil Engineer and RED HORSE units across the USAF. Each participant must have experience in designing, managing, or constructing UBM, FrameCAD, and PEB facilities. Since there are very few individuals with all three of these contingency construction method experiences, the Delphi method is ideal to get each of their opinions and experiences. Participants were initially interviewed for availability and commitment via email conversations and during research trips to the Air Force Civil Engineer Center (AFCEC), Silver Flag, Nellis AFB, and Malmstrom AFB. As previously defined in chapter 1, contingency construction experts for this research are active duty Airmen, Reserve Airmen, Guard Airmen, and/or retired or separated Airmen that intimately worked with RHS vertical construction assets/methods for at least 1 year and have deployed a minimum of 1 time. With a minimum of 1 year of construction experience on a given system and 1 deployment, this may create some bias among the SME's. Bias in this research will be referred to as the inclination or prejudice for or against one of the construction systems being evaluated. This bias will be further explored in the Limitations section below.

3.4 Implementation

With the Air Force Institute of Technology's IRB approval, participants/subject matter experts were sent each round of questions. Each participant was also provided a general consent form as part of round 1 which also assured each participant that no names would be attributed to any of the opinions or experiences given. Additionally in Round 1, demographics were taken on each of the subjects to obtain background information. The demographics asked for in the first round of questions were:

- Level of Education
- Current Job Title

- Level of Expertise
- Years of Experience
- Number of Deployments
- Number of Construction Projects

The additional questions in the first round of the Delphi Method are:

- What is the “best” contingency construction equipment for vertical construction?
- What are the top 3 USAF’s contingency construction limitations?
- What are the Pros & Cons of the UBM?
- What are the challenges of the UBM?
- What are the Pros & Cons of the FrameCAD?
- What are the challenges of FrameCAD?
- What are the Pros & Cons of the PEB method?
- What are the challenges of the PEB method?
- Is the USAF currently providing enough training for vertical contingency construction?
- Are there other vertical contingency construction systems or methods that may be needed in the USAF?

The email sent to all potential participants can be seen in Appendix A and the first round’s questionnaire can be seen in Appendix B. Once answers from the first round of questions are received, the second round of questions will be developed and then sent out to the active participants. This second round of questions will be interpreted, possibly

resulting in a consensus of the opinions of each contingency construction method. If no consensus is gained after two rounds of questions, a third round of questions may be sent in order to gain necessary consensus from the respondents.

3.5 Demographics

As discussed in the Participants and Implementation section, it is imperative to establish each of respondents as a SME. In Hasson et al's article, "studies employing the Delphi make use of individuals who have knowledge of the topic being investigated, which can be defined as a 'panel of informed individuals'; hence the title 'experts' being applied" [27]. The article goes on to state that the commitment of participants to complete the Delphi process is often related to their interest and involvement with the questions being researched [27]. The research team gathered candidates for SME's from the multiple site visits and during discussions with members in the RED HORSE and Civil Engineer community. The following questions were asked of each respondent to confirm if each respondent actually qualified as a SME for this research:

- What is your rank?
- What is your current job title?
- What is your Air Force Specialty Code?
- What is your deployment experience - how many? Where? What did you do?
- How many years of experience do you have with the following systems:
 - UBM K-Spans?
 - PEB's?
 - FrameCAD?
 - Other Construction Systems (Please List)

Out of the 14 respondents, 4 were Majors, 4 were Captains, 1 was a Senior Master Sergeant, 1 was a Master Sergeant, 3 were Technical Sergeants, and 1 was Staff Sergeant. In all, 8 were officers, and 6 were enlisted. All of the respondents have done at least one tour at a RHS. The job titles were all very diverse, ranging from 4 being structural craftsmen, a cantonments superintendent, an instructor, a commander, a project engineer, a flight commander, an engineer advisor, a flight chief, a resources chief, an acquisitions program manager, and a branch chief. Much less diverse than job titles, 5 respondents were structures Airmen, 1 was an HVAC Airmen, and 8 were engineer officers.

In order to verify contingency experience, each respondent was asked to report how many deployments they had been on. If a respondent would have reported no deployments, they would not have been considered a SME for this research. Each respondent also had room in the survey to explain where they have individually gone and what they have done during the deployments. Although this question does not guarantee that any of the respondents were more familiar with any of the construction systems and methods being analyzed, it does indicate that each of them has been in and worked in austere or remote conditions around the world where these methods and systems are being used or could be used. The minimum deployments was 1, 2 individuals had 6 (max), with the rest ranging from 2 to 5 each. The total number of deployments between all 14 respondents was 46, which ended up being an average of 3.2 deployments per respondent.

In addition to contingency experiences, each respondent was also asked to report how many years of experience they had on each contingency construction system being evaluated and/or any other construction systems they had experiences on.

For the UBM, every respondent had experience ranging from 1 year to a maximum of 19 years. There was a total of 80.5 years of experience reported for the UBM system, with an average of 5.75 years per respondent.

For the PEB method, 12 out of 14 respondents reported experience. The two respondents that reported zero years of experience will not be considered an expert for the PEB method and none of their answers will be considered during the PEB's method analysis. For the respondents that did have PEB experience, the minimum reported was 3 years, with a maximum of 19 years. Based on the 12 respondents reporting PEB experience, the average was 7 years of experience per respondent and the total years reported was 84.5.

For the newest method, FrameCAD, 10 of the 14 respondents reported experience, which ranged from 1 year to the maximum of 5 years. The 4 respondents that did not report experience with FrameCAD will not be considered experts for this system and will not have any of their responses analyzed for FrameCAD. The total number of years of experience reported for FrameCAD was 19 years, with an average of 1.9 years per respondent.

Finally, 9 out of 14 respondents annotated that they had experiences in other construction systems or methods which included CMU block, concrete, utility projects, traditional wood, concrete tilt-up, tent/fabric structures construction and/or masonry.

Based on these demographics, all respondents are considered SME's for deployment experience and using the UBM based on the minimum requirements. For the PEB method and FrameCAD, not all respondents reported experience with it for more than a year, thus each that did not will not be considered a SME for that respective system or method, and none of their respective answers for those systems or methods will be part of this research's analysis. A visual compilation of the demographics by each of the respondents can be seen in Figure 3.2.

3.6 Research Questions Analysis

After collecting demographics on each respondent to verify if each was considered a SME, open ended questions were asked to gain opinions and beliefs based on this research's definition of contingency construction. This research defines contingency

#	A	C	D	E	F	G	H	I	J	K	L
		Bl	Job Title	AFSC	Deploy	UBM	PEE	FC	Other Exp		
1											
2			Maj Commander	32E4	4	15	15	2			
3			2 TSgt Structural Craftsman	3E371	2	19	19	2	CMU Block		
4			3 Maj Emergency Services Branch Chief	32E4	3	3	3	0	Concrete (Cast-in-place/Tilt-up/Pre-Cast), Timber Frame, CMU		
5			4 Capt Engineer Advisor	32E3G	3	1	3	1	Utility projects, LAMS construction		
6			5 SMS Cantonments Superintendent	3E490	4	2	0	2			
7			6 TSgt Structural Craftsman	3E371	5	7	3	1			
8			7 MSG Structures Alpha Flight Chief	3E371	6	10	8	5	SWA Huts(30+), large variety of tent systems to include LAMS, MSS90, TEMPERs, MSS, SSS, Spung Shelters and GPMs.		
9			8 Maj Instructor	32E	3	4	5	0	Traditional Wood Frame, CMU		
10			9 SSgt Structural Craftsman	3E3X1	2	2	0	1	CMU Block		
11			10 TSgt Structural Craftsman, Assistant NCC	3E371	3	2	5	1	Concrete tilt-up		
12			11 Maj Air Base Acquisitions Program Manager	32E4	6	6	10	0	Concrete tilt-up/precast, Cast-in-place concrete, fabric structures, modular buildings, and other relocatable metal buildings		
13			12 Capt Chief, CE Resources	32E4	2	3.5	3.5	0	Reinforced Concrete, Masonry, Stress-tensioned fabric, wood		
14			13 Capt Engineering Plt OIC	32E3E	2	3	3	1	None		
15			14 Capt Project Engineer	32E5	1	3	7	3	None		
16				Total:		46	80.5	84.5	19		
17				Avg:		3.28571429	5.75	7.0417	1.9		
18						>1 deployment	14 of 14	12 of 14	10 of 14	For analysis	
19											
20											
Demographics Best and Challenges UBM UBM (2) PEB PEB (2) FrameCAD FrameCAD (2) Training or Other Methods											

Figure 3.2: Demographics Visual Compilation

construction as military forces constructing vertical facilities (specifically Pre-Engineered Buildings (PEB), Ultimate Building Machine (UBM) K-Span's, or FrameCAD facilities) at natural disasters, terrorist events, subversive responses, military operations, humanitarian operations, or remote operations. Traditionally, contingency construction has been limited from initial bed down to 2 years, however, this thesis does not limit the contingency timeline and it is considered from bed down to base closure, site closure, or mission completion.

The following questions were asked of each SME based on this research's definition of contingency construction and each of their own experiences and expertise:

1. What do you believe is the best contingency construction equipment or method for vertical construction? Why?
2. What are the top 3 USAFs contingency construction challenges? Please elaborate.
3. Regarding UBM and K-Span construction: 1) What are the Pros & Cons of using the UBM? 2) What are the unique challenges of using UBM?
4. Regarding Pre-Engineered Buildings: 1) What are the Pros & Cons of using the PEBs? 2) What are the unique challenges of using PEBs?
5. Regarding the FrameCAD system: 1) What are the Pros & Cons of using the FrameCAD system? 2) What are the unique challenges of using FrameCAD?

6. Is the USAF providing enough training for vertical contingency construction?
Explain.
7. Are there other vertical contingency construction systems or methods that may be needed in the USAF? Please elaborate.

In order to analyze the multitude of answers for these open-ended questions, the researcher isolated the questions into different sections. The first section of analysis consisted of the first two questions. The second section of analysis included the questions regarding the UBM and K-Span construction. The third section of analysis were the questions about PEBs. The fourth section analyzed the FrameCAD system questions, and the final section analyzed the questions concerning training and other possible vertical contingency construction systems or methods that may be needed in the USAF.

Microsoft Excel was used to compile all the answers provided and break down the answers into general themes or words. After analyzing all the applicable answers for each question, the general themes or words for each answer were totaled. The general themes or words for each of these questions was then used to achieve consensus or used for the second round of questions. A screen shot of the Excel file used to analyze all the data for the first round of analysis can be seen in Figure 3.3 and as described above, each excel tab represents a different section of analysis based on the questions and answers. In the following chapter, each of the questions and what answers were provided by each of the SME's will be further analyzed using the same methodology as described above.

3.7 Limitations

As initially mentioned in the Participants section, this research could contain some bias toward a system or method. Bias is defined as the inclination or prejudice for or against one of the construction systems being evaluated. As the demographics were collected and evaluated above, each of the participants had experience with the UBM method, but not

	A	B	C	D	E	F	G	H		
1	Participant	Best Contingency Construction	Challenge 1	Challenge 2	Challenge 3	SC 1	SC2	SC3		
1		1 depends on the function of the building and the available lead times for the mission.	Not having the organizational ability to adapt/adapt emerging technologies is eroding our competitiveness to provide a quality and timely product to the warfighter when compared with contingency construction performed by contractors.	An increased reliance on contractors could leave the warfighter without an experienced, in-house execution method for those missions where contractor execution is incompatible with construction objectives (i.e. speed, austere locations, sensitive missions).	Weather - Self explanatory, you need the weather to be in conditions to do any type of construction.	Technology	Contractors			
2		2 If you are looking for an expedition facility to be built your UBM/K-Span will be the best contingency method to use because the facility (overhead storage) can be built in a matter of weeks if you have the right material on hand before construction begins.	Material acquisition - This is the main challenge when it comes to construction, if you don't have the right parts or the parts period the building will not go up.	Weather - Self explanatory, you need the weather to be in conditions to do any type of construction.	Personnel Experience - With anything we do you need to right amount of people as well as personnel with the knowledge and experience in doing the job your doing.	Materials	Weather	Personnel		
3		3 K-Spans given robust training, proven ability to adjust to sites, ability to reduce/limit major logistical hurdles given simplicity of structure, solid return on investment given nominal construction timespan, interior floor space.	Adequately planning for work beyond primary structure, i.e. finishes, mechanical, electrical etc extend projects to long	Insufficient design training leading to inability to adapt designs to sites, driving re-design	Inability to manage actual construction, no actual schedules or adherence to them.	Planning	Designs	Scheduling		
4		4 K-Spans because they are quick/expedient, cheap, and easy to construct. I say this because nowadays base closure could be years down the line instead of a quick operation. However, for events like natural disasters, I think soft skin structures would be a better option, construction-wise since they are even quicker to construct and short-term.	Materials: Many times material does not arrive on time or correctly and the procurement process has a lot of red tape and areas for bottlenecks (contracting).	Equipment: It takes a long time to get equipment/UTCs overseas.	Technical expertise: The Air Force does not stress a lot of technical expertise and you kind of need it in austere locations when you might not have a lot of reach back... especially for something like FrameCAD. Bickering amongst other units: A lot of different organizations want a piece of the pie which causes a lot of in-fighting within the Air Force (RED HORSE vs. Prime BEEF vs. CRG) on who gets to do what.	Materials	Equipment	Personnel		
5		5 In my experience the Ultimate Building Machine may be the best piece of equipment for contingency construction. It is smaller and more maneuverable than a Frame CAD machine. It sets up much faster and easier than the amount of work that goes into leveling and preparing a site for a Frame CAD machine.	In a deployed environment it can be very challenging getting materials needed for construction, especially quality materials.	Likewise, the same can be said about construction equipment. Both can be extremely challenging to acquire in a remote location. This may be where the Frame CAD machine beats out the UBM in that you don't need as much heavy equipment to construct a Frame CAD building (once the foundation is poured) as required to construct a UBM.	Additionally, training can become an issue if members have PCS'd in and out of the unit and don't have any experience with a UBM or Frame CAD.	Materials	Equipment	Personnel		
6		6 PEBs are our best form of vertical construction, due to the building life span and quick erection time. Also the numerous variations of length, size and height allow endless possibilities.	Materials- It can be a hassle to get all the materials you need for your project.	Tools- Having all the tools available to get your project done.	Experience- People not having gained the knowledge to do heavy construction.	Materials	Equipment	Personnel		
7										
		Demographics	Best and Challenges	UBM	UBM (2)	PEB	PEB (2)	FrameCAD	FrameCAD (2)	Training or Other Methods

Figure 3.3: Excel File Screen Shot 1 - Best and Challenges Tab

necessarily equal amounts compared to all methods/systems discussed and evaluated. As each of these question's answers are analyzed, the UBM method's bias may show up. If bias does show up, it will be further analyzed and discussed in the final chapter of this thesis.

3.8 Summary

The Delphi Method is an ideal way to gain geographically dispersed experts opinions in order to provide a consensus on a topic. Analyzing and understanding the USAF's contingency construction methods is essential to furthering the Civil Engineer community's corporate knowledge. Knowing the opinions and experiences of experts that have used and dealt with each contingency construction method has not been accomplished before.

With the responses from each participant, the Results and Discussion chapter will seek to further understand and analyze the overall consensus of each round of questions.

Chapter 5 will then conclude this thesis' impacts, provide inputs into Civil Engineer policy and guidance (such as the Sand Book) and recommend possible additional research avenues pertaining to contingency construction methods.

IV. RESULTS & DISCUSSION

BASED on the in-depth literature review of each vertical construction system currently in use by RED HORSE and using the Delphi Method, this chapter discusses each round of questions and reports the respective results. This chapter will also define what consensus is for this research, what questions were asked during each round and what were the answers, what overall analysis was conducted after each round, and was there consensus found after the multiple rounds.

4.1 Definition of Consensus

Considering multiple articles that have used and evaluated the Delphi method, there currently is no standard that defines consensus. An article published by Research Gate evaluated multiple Delphi studies and discussed the differences in consensus which included 51%, 70%, and even suggested that the “stability of the response through a series of rounds is a more reliable indicator of consensus” [27]. Since there is no firm answer for the definition of consensus, this research will use an average of the 2 values listed above which is 60%. Therefore, if the SME’s have an agreeance rate of 60% or greater, this research will consider consensus to have been achieved.

4.2 Round 1 Analysis

The first round of analysis for this Delphi study breaks down each of the questions in the Delphi study questionnaire and summarizes the SME’s answers into simplified answers and general themes. As described in the Methodology chapter, excel was used to sort and decipher all of the SME’s answers. It is also important to note that some of the theme’s definitions derived will differ from question to question in this analysis. The following sub-sections go through each specific question and what analysis was conducted.

4.2.1 Section 1 Analysis - The “Best” Contingency Construction Method and The Top Contingency Construction Challenges.

The first section of analysis compiled all the answers into one column to the question: “What do you believe is the best contingency construction equipment or method for vertical construction? Why?” By viewing all the answers at one time, the researcher then could color code the answers based on the answers given. This color code scheme and a sampling of the answers provided by the SME’s can be seen in Figure 3.3. For this question, 7 SME’s answer was the UBM, 2 SME’s answer was the PEB method, 2 SME’s answer was the FrameCAD system, and 3 SME’s did not provide a direct answer to the question. Based on these answers, the researcher decided that since only 11 answers contained a system or method, the 3 that did not answer the question were eliminated. Out of the 3 SME’s that did not directly answer this questions, 2 of them did not have any experience with FrameCAD. Conversely, out of the 11 SME’s that did answer the question, 2 did not have experience with PEBs and 2 did not have experience with FrameCAD. Overall, with 63% (7 of 11) of the responses in agreeance, it was determined that UBM achieved consensus for being generally the “best” contingency construction equipment or method for vertical construction.

Out of the 7 SME’s that answered UBM, one said “if you are looking for an expedition facility to be built...UBM K-Span will be the best contingency method to use because the facility (overhead storage) can be built in a matter of weeks if you have the right material on hand before construction begins.” Another SME stated K-Spans were best “given robust training, proven ability to adjust to sites, ability to reduce/limit major logistical hurdles given simplicity of structure, solid return on investment given nominal construction timespan, interior floor space, customization, etc.” Similar to the last SME’s opinion, a different SME agreed that K-spans were best “because they are quick/expedient, cheap, and easy to construct.” Commenting on the logistics of the UBM, another SME stated that

the UBM “is smaller and more maneuverable than a Frame CAD machine...it sets up much faster and easier than the amount of work that goes into leveling and preparing a site for a Frame CAD machine.” Finally, another SME stated that K-Spans are “low cost, long life, and speed of design/production...RED HORSE can produce a K-Span from idea to completion in two months, with a very simple design and material that can be kept on-hand.”

Also in the first section of analysis, the second question was broken down into 3 separate columns to divide up each of the 3 top contingency construction challenges. In addition to each of these 3 columns, an additional 3 columns were created to the right of the original answers (as can be seen on the right side of Figure 3.3). These new columns were used to place a general word or theme based on the answers of all of the SMEs. There were 17 different themes identified based on the responses from the 14 SME’s. The themes were (in ranking order from highest to lowest): materials, personnel, equipment, training, technology, quality, direction, longevity, weather, requirement, standardization, decision, contractors, money, designs, scheduling, and planning. Based on these synthesized answers and extracted themes, the top 3 challenges were materials (10), personnel (9), and equipment (4). These themes were then used for the second round of questions and used to build a consensus from all the SMEs. All of the themes and the top theme’s definitions derived from the SME’s answers for contingency construction challenges can be seen in Table 4.1.

4.2.2 Section 2 Analysis - UBM/K-Span.

The second section of analysis compiled all the SME’s answers that pertained to the UBM/K-Span construction. For each of the SME’s answers, a column was created in order to view all the responses at the same time. Similar to section 1’s analysis, new columns were created based on the 3 to 4 themes or meanings extracted from each SME’s answer to the question. It is also of note that each respondent was considered a SME for the UBM

Table 4.1: Contingency Construction Challenges Themes

Contingency Challenges			
Theme	Total	%	Definition
Materials	10	71%	due to poor procurement timelines and/or quality
Personnel	9	64%	due to right amount and/or lack of expertise or training
Equipment	4	29%	due to the logistics/timing of moving it and/or having the right pieces available
Training	3	21%	
Technology	2	14%	
Quality	1	7%	
Direction	1	7%	
Longevity	1	7%	
Weather	2	14%	
Requirement	1	7%	
Standardization	1	7%	
Decision	1	7%	
Contractors	1	7%	
Money	1	7%	
Designs	1	7%	
Scheduling	1	7%	
Planning	1	7%	

since each had reported experience in using the asset. A portion of the analysis of the UBM/K-Span questions compiled into Excel can be seen in Figure 4.1.

	A	B	C	D	E	F	G	H
1	Participant	UBM Pros	UBM Cons	UBM Challenges	UBM Pro 1	UBM Pro 2	UBM Pro 3	UBM Pro 4
2	1	bench-stocked materials, large free-spans, simplicity	wasted space at wall, aesthetics, \$ to MIC	Many times RH ends up constructing a building within a building (i.e. an interior buildout using the K-Span as a roof).	Materials	Space	Simplicity	
3	2	The pros when it comes to using the UBM is that it is easy to set up and operate. It can be transported easily to any deployed location.	The cons to using the UBM is having enough personnel to help with the carrying of panels when the metal comes off the machine.	Unique challenges using the UBM is picking the right location to set up the machine because depending on the size of the facility you will need to establish a huge foot print for producing the arches for the building. Also you will need crane support when lifting the UBM arches.	Simplicity	Transportable		
4	3	standardized designs easing design burden, ability to customize open space, spectrum of sizes, relatively simple physical construction	no ability to TRULY customize, limits given weather, wind, cannot make use of ALL interior space, necessities for cranes, specialized equipment	Must be trained on UBM; must have software and understanding of design parameters; effectively limited to single floor plan can be longer/shorter and can adjust width some but is always going to be a rectangle; various insulation products and lengthy timelines	Designs	Customizable	Space	Simplicity
5	4	Quick construction, very cookie-cutter, cheap compared to other vertical options (fits well for contingency construction...not pretty, but effective).	Dimensions are essentially the same, just bigger or smaller, so it may not meet specific requirements for facilities. Can't tailor the facility as well as other vertical options.	Need to ensure personnel are properly trained to operate machine. Usually there is only one UBM on-site so if that goes down and materials are hard to come by then you're screwed.	Speed	Simplicity	Cheap	
6	5	It is easily moved and set in place to begin use and construction. Once the UBM is in place and ready to run, a crew can set up all the steel pics for an entire K-span in a single day.	However, you are restricted to a simple K-Span design which may not be ideal in every situation. Additionally, UBMs typically won't operate correctly below freezing temperatures. If they have any frost on them they'll struggle to create proper steel arches.	To install the steel arches from a UBM the crew requires a crane which may not always be easily acquired. Also, a UBM requires a relatively large crew compared to FrameCAD construction. For K-Span assembly, you would need a crew of 5 running the UBM machine. You would require a crew of 5 to carry each steel arch from the machine to be seamed with other steel arches. You would need a crane crew, and you would need a crew of 5 or more seaming the steel arch pics together as the building goes up. Again, a UBM does not operate well in freezing temperatures.	Transportable	Speed		
		Its a expedient way for vertical construction. You can have a building up within a month. Once you got you width and	Typically a K-span is only a 20 year building life. It takes a lot of personnel to put the shell up, and if you don't have enough	The challenges of using the UBM in a deployment is the maintenance of the machine. Not knowing how long it has been sitting or knowing the last	Speed	Space		
Demographics Best and Challenges UBM UBM (2) PEB PEB (2) FrameCAD FrameCAD (2) Training or Other Methods								

Figure 4.1: Excel File Screen Shot 2 - UBM/K-Span Analysis Tab

Although there were only 2 questions that discussed the UBM/K-Span, the first question was broken down into 2 sets of answers for simplicity. The first column of responses contained all the answers considering the UBM pros, the second column of responses contained all the answers considering the UBM cons, and the third column contained all the answers for the second question asking about the UBM's challenges.

There were 10 different themes or meanings derived from the multitude of answers for the UBM pros which included (in ranking order from highest to lowest): speed, transportability, simplicity, space, material, cheap, design, contractor support, customizable, and familiarity. Speed and Transportability were part of 7 different SME's answers and Simplicity and Space were part of 6 different SME's answers. The top 4 reported answers, speed, transportability, simplicity, and space, were all used for the second round of questions and used to build consensus from all the SMEs. The entire breakout of reported UBM pro themes and the top theme's definitions can be seen in Table 4.2.

Table 4.2: UBM Pro Themes

UBM/K-Span Pros			
Theme	Total	%	Definition
Speed	7	50%	based on how fast a UBM facility can be built
Transportable	7	50%	based on the maneuverability of the UBM
Simplicity	6	43%	based on the minimal engineering effort needed and/or designs
Space	6	43%	based on the ability to change dimensions or vary sizes per customer requirements
Materials	5	36%	
Costs	2	14%	
Design	2	14%	
Contractor Support	1	7%	
Customizable	1	7%	
Familiarity	1	7%	

Much higher than the pros, the cons portion of the question was derived into 14 different themes or meanings. The cons themes reported were (in ranking order from highest to lowest): customization, space, personnel, lifespan, aesthetics, engineering, limits, costs, materials, repairs, setup, size, usage, and waste. Both customization and space were part of 6 different SME's answers and personnel was derived from 5 different

SME's answers. These top 3 answers, customization, space, and personnel, were all used for the second round of questions in order to build consensus from all the SMEs on this subject. The reported UBM con themes and the top theme's definitions can be viewed in Table 4.3.

Table 4.3: UBM Con Themes

UBM/K-Span Cons			
Theme	Total	%	Definition
Customization	6	43%	based on a limited amount of designs
Space	6	43%	based on the ability to change dimensions or vary sizes per customer requirements
Personnel	5	36%	based on the amount of personnel needed to support the UBM construction effort
Lifespan	3	21%	
Aesthetics	2	14%	
Engineering	2	14%	
Limits	2	14%	
Costs	1	7%	
Materials	1	7%	
Repairs	1	7%	
Setup	1	7%	
Size	1	7%	
Usage	1	7%	
Waste	1	7%	

For the UBM/K-Span challenges section, 13 different themes or meanings were extracted from the SME's provided answers. The UBM/K-Span challenges themes were (in ranking order from highest to lowest): equipment, materials, personnel, training, build-out, location, waste, customer, maintenance, simplicity, size, speed, and weather. The top 4 answers, equipment, materials, personnel, and training, were all used for the second round of questions in order to build consensus from the SME's on the top challenges of the UBM/K-Span. The UBM challenges themes and the top theme's definitions can all be seen in Table 4.4.

Overall, it was interesting to see that so many themes crossed between the pros, cons, and challenges questions for UBM/K-Span analysis. For example, the theme "material" was an answer in all three of the responses and "space" was identified as a top answer for

Table 4.4: UBM Challenges Themes

UBM/K-Span Challenges			
Theme	Total	%	Definition
Equipment	5	36%	due to equipment needed ie craine and/or there only being one UBM available
Materials	5	36%	due to various products available and their respective logistics and/or steel availability
Personnel	4	29%	based on the amount of people needed to carry each steel arch and/or personnel trained on the UBM
Training	4	29%	due to limited amount of training on the UBM
Buildout	3	21%	
Location	2	14%	
Waste	2	14%	
Customer	1	7%	
Maintenance	1	7%	
Simplicity	1	7%	
Size	1	7%	
Speed	1	7%	
Weather	1	7%	

both “pros” and “cons”. With similar themes presenting themselves in multiple questions, this was cause for further exploration with SME’s in the following rounds of questions. Table 4.5 shows the theme’s for each question, the top themes, and the themes that were reported in different categories of questions.

Table 4.5: UBM/K-Span Themes and Relationships - Round 1 Questions

UBM/K-Span Method		
Pros	Cons	Challenges
Speed	Customization	Equipment
Transportable	Space	Materials
Simplicity	Personnel	Personnel
Space	Lifespan	Training
Materials	Aesthetics	Buildout
Costs	Engineering	Location
Design	Limits	Waste
Contractor Support	Costs	Customer
Customizable	Materials	Maintenance
Familiarity	Repairs	Simplicity
	Setup	Size
	Size	Speed
	Usage	Weather
	Waste	
	Key:	
	Top Answers	
	2 Categories	
	3 Categories	

4.2.3 Section 3 Analysis - PEB.

The third section of analysis compiled all the SME's answers that were directed toward PEB construction. For each of the SME's answers, a column was created in order to view all the responses at the same time. Similar to section 1 and 2's analysis, new columns were created based on the 3 to 4 themes or meanings extracted from each SME's answer to the question. An example of the PEB's questions' analysis conducted in Excel, as described in this paragraph, can be seen in Figure 4.2. It is also important to note that due to 2 of the respondents not reporting any experience in PEB construction, their respective answers were not a part of this analysis.

	A	B	C	D	E	F	G	H
1	Participant	PEB Pros	PEB Cons	PEB Challenges	PEB Pro 1	PEB Pro 2	PEB Pro 3	PEB Pro 4
2	1	more permanent, aesthetics, efficient space usage, no technology owner (MIC, FrameCAD), crossover experience available from civilian sector to leverage ARC	long lead times	RH doesn't typically have bench-stocked PEBs. The long lead time creates timeliness issues for material procurement for rapidly changing mission timelines.	Permanent	Aesthetics	Space	Low Tech
3	2	Pros to using a PEB is that the building comes prepackaged and labeled, so it should bolt together without any complications.	Cons to using a PEB is getting the foundation footers correctly so that you do not have any issues when installing the vertical posts.	PEB's unique challenges are making sure that the foundation footers are placed correctly and square so when you are placing the vertical posts you do not have any issues when it comes to tying in the beams for the PEB.	Simplicity			
4	3	ability to customize floor plan/height, better use of available space, more options with interior, stories, mech/elec systems	Insulation techniques are not as standardized, longer lead times on materials/steel, complexity of construction, higher level of finish often leads to delays	The higher level of customization of facilities, basically each is a one-off leads to facility unique material and design issues that have to be resolved in the field and not all teams are prepared to do so. As facility is a one-off steel members are then project specific and there is a long lead time there, leading to an agility/responsiveness issue.	Customizable	Space	Options	
5	4	Can be tailored to withstand any environment or user need (not a basic cookie-cutter structure), structure goes up fast once foundation complete.	Foundation requires more accuracy and alignment of column footers, structural steel and panels are a very long procurement process, takes a little longer to build, usually more expensive	Footer design and alignment. Material procurement.	Customizable	Speed		
6	5	I have never worked with a Pre-Engineered Building	I have never worked with a Pre-Engineered Building	I have never worked with a Pre-Engineered Building				
7	6	Once the project is complete you have a 50 year life on PEB.	If you don't have the a crane support or genie lifts to erect your steel you won't be able to go vertical until you have that equipment available to use.	The biggest hassle of PEB's is getting your footer correct, and making sure you have the equipment you need to start construction.	Permanent			
8	7	Very universal in what the PEB can be used for. Adaptable design and a solid facility.	Much more extensive designing and planning. Requires a larger team. Largest downfall is the time required and the establishment of the columns utilizing the j-bolts.	Many different manufacturers causing several differences in construction from one facility to the next. Again, column placement and j-bolt patterns are the most time consuming, however, this is also a more outdated way of securing this style facility as many contractors use faster anchoring systems.	Customizable	Design		

Figure 4.2: Excel File Screen Shot 3 - PEB Analysis Tab

Although there were only 2 questions that discussed PEB construction, the research team broke down the first question into 2 sets of answers for simplicity and analysis. The first column of responses contained all the answers considering PEB pros, the second column of responses contained all the answers considering PEB cons, and the third column contained all the answers for the second question asking about PEB challenges.

There were 14 different themes or meanings derived from the multitude of answers for the PEB pros which included (in ranking order from highest to lowest): customizable, permanent, aesthetics, simplicity, space, engineering, personnel, designs, equipment, flexibility, low tech, options, speed, and support. Customizable was part of 6 different SME's answers and permanent was part of 4 different SME's answers. The top 2 answers, customizable and permanent, were both used for the second round of questions and used to build consensus from all of the SME's. All of the PEB pro themes, the top theme's definitions, and there respective counts can be seen in Table 4.6.

Table 4.6: PEB Pro Themes

PEB Pros			
Theme	Totals	%	Definition
Customizable	6	50%	based on the ability to customize floor plans and designs for each project
Permanent	4	33%	based on the life span of PEBs
Aesthetics	3	25%	
Simplicity	3	25%	
Space	3	25%	
Engineering	2	17%	
Personnel	2	17%	
Designs	1	8%	
Equipment	1	8%	
Flexibility	1	8%	
Low Tech	1	8%	
Options	1	8%	
Speed	1	8%	
Support	1	8%	

Much lower than the pros, the cons portion of the question was derived into 8 different themes or meanings. The cons themes were (in ranking order from highest to lowest): logistics, cost, equipment, foundation, assembly, engineering, standardization, and finish. Logistics was part of 9 different SME's answers, cost was part of 5 different SME's answers, and both equipment and foundation were part of 4 different SME's answers. These top 4 answers, logistics, cost, equipment, and foundation, were all used for the second round of questions in order to build consensus from all the SME's on PEB construction. All of the PEB con themes and the top theme's definitions can be viewed in Table 4.7.

Table 4.7: PEB Cons Themes

PEB Cons			
Theme	Totals	%	Definition
Logistics	9	75%	based on the long procurement timelines/process and/or delivery
Cost	5	42%	due to the cost of using a contractor for designs/procurement of the building
Equipment	4	33%	based on the specific equipment needed for construction
Foundation	4	33%	based on the foundation/columns needing to be accurate/precise and/or the time this takes
Assembly	3	25%	
Engineering	2	17%	
Standardization	2	17%	
Finish	1	8%	

During the PEB challenges analysis, 9 different themes or meanings were extracted from the SME's provided answers. The PEB challenges themes were (in ranking order from highest to lowest): logistics, foundation, designs, customizable, equipment, material, training, assembly, and engineering. Logistics was part of 6 different SME's answers and foundation was part of 5 different SME's answers. The top 2 answers, logistics and foundation, were both used for the second round of questions in order to build consensus from the SME's concerning the top challenges of PEB construction. All of the PEB challenges themes and the top theme's definitions are shown in Table 4.8.

Table 4.8: PEB Challenges Themes

PEB Challenges			
Theme	Totals	%	Definition
Logistics	6	50%	based on the time required for design, manufacturing, and delivery of the PEB
Foundation	5	42%	based on placing the foundation footers or columns correctly and/or the time this takes
Designs	3	25%	
Customizable	2	17%	
Equipment	2	17%	
Material	2	17%	
Training	2	17%	
Assembly	1	8%	
Engineering	1	8%	

Similar to the UBM's analysis, it was observed that many themes crossed between the pros, cons, and challenges questions for the PEB method's analysis. For example, both engineering and equipment were answers found in all three of the responses and logistics

was top answer for both cons and challenges. With these similar themes appearing in multiple questions' responses, this was cause for further exploration with the following rounds of questions. Table 4.9 shows the theme's for each PEB question, the top themes, and the themes that were reported in multiple different categories of questions.

Table 4.9: PEB Themes and Relationships - Round 1 Questions

PEB Method		
Pros	Cons	Challenges
Customizable	Logistics	Logistics
Permanent	Cost	Foundation
Aesthetics	Equipment	Designs
Simplicity	Foundation	Customizable
Space	Assembly	Equipment
Engineering	Engineering	Material
Personnel	Standardization	Training
Designs	Finish	Assembly
Equipment		Engineering
Flexibility		
Low Tech		
Options		
Speed		
Support		
	Key:	
	Top Answers	
	2 Categories	
	3 Categories	

4.2.4 Section 4 Analysis - FrameCAD.

The fourth section of analysis compiled all the SME's answers that were in reference to the FrameCAD asset. For each of the SME's answers, a column was created in order to view all the responses at the same time. Similar to the last 3 sections analysis, new columns were created based on the 3 to 4 themes or meanings pulled from each SME's answer to the question. It is also important to note that 4 contingency construction SME's responses to these questions were not analyzed due to them not reporting any experience with the FrameCAD asset. An example of the analysis conducted in Excel for the FrameCAD questions can be seen in Figure 4.3.

	A	B	C	D	E	F	G	H
1	Participant	FrameCAD Pros	FrameCAD Cons	FrameCAD Challenges	FC Pros 1	FC Pros 2	FC Pros 3	FC Pros 4
2	1	bench-stocked materials, ease of construction, adaptable	start-up cost, increased training on taxed craftsmen	It's a technology that's not readily-accepted and the equipment is not currently on RED HORSE UTCs.	Materials	Simplicity	Adaptable	
3	2	Pros to the FrameCAD machine is that it's a very easy system to use if the software/design is developed correctly.	Cons to using the FrameCAD is the software needs to be updated yearly, someone needs to know how to use FrameCAD detailer/structure software. Because with having someone knowledgeable using detailer or structure you have a machine that can't be used.	Challenges to the FrameCAD is the software needs to be updated yearly, someone needs to know how to use FrameCAD detailer/structure software. Because with having someone knowledgeable using detailer or structure you have a machine that can't be used.	Simplicity			
4	3	Insufficient experience to have an informed opinion.	Insufficient experience to have an informed opinion.	Insufficient experience to have an informed opinion.				
5	4	Fast production of steel members, can be tailored to meet user requirements, transportable	Most people have never heard of it or are trained on it, very small market for replacement parts or building materials, not readily available	No one knows about it...	Speed	Adaptable	Transportable	
6	5	A FrameCAD system offers the opportunity to design and build a more complex facility. Anything that can be designed within the scope of the FrameCAD software can be printed and constructed from the machine. Once printing of steel frame begins, the building walls can be constructed in a matter of hours. It is remarkably fast to put the printed walls together.	Unfortunately, the FrameCAD machine is a more complex piece of equipment and can (and does) breakdown. This can leave an average construction crew without the means to easily repair it.	The FrameCAD machine uses an extensive hydraulic system which is susceptible to failure. This can create long delays if problems arise. Additionally, the unit has to be placed on solid level ground. This may require a great deal of time being spent preparing an area just for the FrameCAD machine to sit and operate. Once this is accomplished, it is not easily moved to another location.	Adaptable	Speed		
7	6	Being able to produce a building from a machine in days, how it punches all the holes for the screws and simple the erection is.	The availability of replacement parts can be a challenge, if something on the FrameCad machine breaks, it has the potential to shut down your project until replacement parts come in.	The challenges of using the FrameCad machine are you need to have a operator who is versed in running the machine and able to do the maintenance on it. If a small part breaks on it and you don't have a replacement it could potentially shut down your construction site.	Speed	Simplicity		
		Demographics	Best and Challenges	UBM	UBM (2)	PEB	PEB (2)	FrameCAD
								FrameCAD (2)
								Training or Other Methods

Figure 4.3: Excel File Screen Shot 4 - FrameCAD Analysis Tab

Similar to the UBM and PEB analysis sections, there were only 2 questions that discussed the FrameCAD asset, however, the researcher broke down the first question into 2 sets of answers for simplicity and analysis. The first column of responses contained all the answers considering the FrameCAD's pros, the second column of responses contained all the answers considering the FrameCAD's cons, and the third column contained all the answers for the second question asking about the FrameCAD's challenges.

There were 8 different themes or meanings derived from the answers for the FrameCAD system pros which included (in ranking order from highest to lowest): adaptable, simplicity, speed, transportability, efficiency, maintenance, materials, and personnel. Adaptable and simplicity were part of 6 different SME's answers and speed was part of 5 different SME's answers. Being the top 3 reported answers, adaptable, simplicity, and speed, were all used for the second round of questions and used to build consensus from all of the SME's. All of the FrameCAD pros themes and the top theme's definitions can be seen in Table 4.10.

Table 4.10: FrameCAD Pro Themes

FrameCAD Pros			
Theme	Totals	%	Definition
Adaptable	6	60%	based on the ability to be tailored to user requirements and/or anything can be designed
Simplicity	6	60%	based on the ease of use between the software and hardware and/or the actual construction
Speed	5	50%	due to how fast the machine can produce an entire building
Transportable	3	30%	
Efficient	1	10%	
Maintenance	1	10%	
Materials	1	10%	
Personnel	1	10%	

With 50% more answers than the pros, there were 12 different themes or meanings derived from the answers for the FrameCAD system cons. The FrameCAD cons themes were (in ranking order from highest to lowest): cost, software, training, complexity, maintenance, material, availability, equipment, limitations, marketing, personnel, and upgrades. Cost, software, and training were all part of 4 different SME's answers and were also the top 3 reported answers. These top 3 reported answers were all used for the second round of questions and used to build consensus from all of the SME's. Each of the FrameCAD's cons themes and the top theme's definitions are shown in Table 4.11.

Table 4.11: FrameCAD Cons Themes

FrameCAD Cons			
Theme	Totals	%	Definition
Cost	4	40%	due to initial costs, re-occurring costs, replacement parts cost, and/or licensing
Software	4	40%	based on the software not working well with other software and/or annual renewals
Training	4	40%	due to minimal personnel being trained on the FrameCAD system
Complexity	2	20%	
Maintenance	2	20%	
Material	2	20%	
Availability	1	10%	
Equipment	1	10%	
Limitations	1	10%	
Marketing	1	10%	
Personnel	1	10%	
Upgrades	1	10%	

For the FrameCAD system challenges question analysis, there were 8 different themes or meanings extracted. The FrameCAD challenges themes were (in ranking order from highest to lowest): maintenance, new, software, training, not official, personnel, cost, and placement. Both maintenance and new were the top 2 reported answers, and both were part of 4 different SME's reported answers. These top 2 answers will both be used for the second round of questions in order to build consensus from the SME's on the top challenges of the FrameCAD system. All of the FrameCAD's challenge themes and the top theme's definitions can be viewed in Table 4.12.

Table 4.12: FrameCAD Challenges Themes

FrameCAD Challenges			
Theme	Totals	%	Definition
Maintenance	4	40%	meaning that the machine needs regular maintenance and/or repair kits
New	4	40%	due to the FrameCAD system not being an official UTC and/or it being a new technology to the USAF
Software	3	30%	
Training	3	30%	
Not Official	2	20%	
Personnel	2	20%	
Cost	1	10%	
Placement	1	10%	

Similar to both the UBM and PEB analysis, many of the themes for the FrameCAD system crossed between the pros, cons, and challenges columns of analysis. Both the maintenance and personnel themes were found as answers in all 3 columns, and the training and materials themes were found in 2 of the columns. Based on the multi-column themes, this area of analysis will be furthered explored in future rounds of questions. Table 4.13 shows the theme's for each FrameCAD question, the top themes, and the themes that were reported in multiple different categories of questions.

Table 4.13: FrameCAD Themes and Relationships - Round 1 Questions

FrameCAD Method		
Pros	Cons	Challenges
Adaptable	Cost	Maintenance
Simplicity	Software	New
Speed	Training	Software
Transportable	Complexity	Training
Efficient	Maintenance	Not Official
Maintenance	Material	Personnel
Materials	Availability	Cost
Personnel	Equipment	Placement
	Limitations	
	Marketing	
	Personnel	
	Upgrades	
	Key:	
	Top Answers	
	2 Categories	
	3 Categories	

4.2.5 Section 5 Analysis - Training and Other Contingency Construction Systems or Methods Needed.

The final section of analysis, pertaining to the first round of questions, asked the SME's about training and if other contingency construction systems or methods are needed. Similar to the other sections of analysis, each answer for both of these questions that was provided by the SME's was transformed into a column in order to view all the answers at once. Since both of these questions answers were either yes or no (and the SME's were provided room to explain), the researcher did not need to create new columns to synthesize the answers into different themes or meanings. An example of the analysis conducted for these final questions can be seen in Figure 4.4.

The first question of this section's analysis was "Is the USAF providing enough training for vertical contingency construction? Explain." Based on the SME's answers, 92% of the experts all agreed that there is not enough training provided by the USAF for vertical contingency construction. Based on this majority of answers, the researcher

A		B	C
1	Participant	Training Question	Other Methods
2		1 The best training is actual construction. In that regard, active-duty is much better off than the ARC component. In the ARC, the primary training opportunity each year is a Deployment-for-Training (DFT). There are very few DFTs that incorporate K-Spans, PEBs or FrameCAD. DFTs are primarily CMU or renovations.	Possibly, but they need to replace an existing technology and not just put more on the craftsmen's plate.
3		2 Yes we have enough training for vertical contingency construction that we now use in the USAF.	The USAF needs to get with outside agencies on what methods (i.e tilt-up building construction) they are using because we are not setting are personnel up for the outside world when it comes to vertical construction.
4		3 Having been RHS, and an ECES/CD: No. There is an expectation that Airmen will make it happen, and they do, but after a learning curve, which means they were not prepared the day they hit boots on ground. Structural steel, reinforced concrete is not something even the most skilled Airmen is effective at off the street.	As mentioned in my experiences, CMU, cast-in-place, and pre-cast construction also have their place. Each has their own niche, but when working in a BP/BC environment they ar
5		4 No. All the vertical construction happening right now in the AOR are PEBs, LAMS, and some K-Spans...most CE troops (which make up the vast majority of the force) have never dealt with this kind of construction yet many times they have to augment RH since RH does not have enough manpower to meet all the requirements.	LAMS/tension fabric structures if the base/location is meant to be temporary like for hurricane relief.
6		5 RED HORSE is doing a tremendous job of training and preparing its Airmen for vertical construction requirements down range. However, it isn't until Airmen get to RED HORSE that they get that kind of training. Most CE Airmen would not be able to accomplish the task of constructing a K-span without a great deal of training and oversight from more experienced technicians that have been in RED HORSE.	None that I know of.
7		6 I think the opportunities are there to get the training and experience home station, but it up to the units to make sure there people are trained and getting ready for the contingency environment back home.	No, I think we are already stretching ourselves to thin with the UBM's, PEBs, and FrameCad construction, and having SME and operators that we don't need to add anymore constructions systems to it.
8		7 My honest opinion is no. Many times funding is an issue with sending people to some type of formal training. Additionally, the old ways of doing things have become a barrier in allowing our Airmen a chance to seek out better ways to perform contingency construction. I also do not believe we have a strong channel to enhance our construction methods. Sending Airmen to advance training courses in Gulfport, MS is not going to improve our knowledge of construction for military operations.	ICF(Insulated Concrete Forms), we utilized these at USAFA and have had numerous other facilities where ICF would have been a much better option. Many facilities at enduring deployed locations require hardened facilities for advanced protection from potential IDF. CMU had been a "go to" for many. ICFs would allow for flexible designs, rigid construction with a monolithic pour. Having first hand knowledge and seeing some of our adaptive construction methods, ICF would also be a better construction method that would provide another advanced capability to our military
		8 No. See #3 in challenges. We are relying on a CCP, which is normally a small enhancement job that happens once a year and maybe silver flag training to keep our Prime BEEF forces ready to	Low tech solutions are a skill we overlook. Depending on the contingency, using locally available materials and methods might be the most effective way to move from initial BEAR asset to
		Demographics	Best and Challenges
		UBM	UBM (2)
		PEB	PEB (2)
		FrameCAD	FrameCAD (2)
		Training or Other Methods	

Figure 4.4: Excel File Screen Shot 5 - Training and Other Methods Analysis Tab

decided to consider this questions as receiving consensus and it did not need to be further analyzed. Some of the SME's explanations when answering this question were:

- funding is an issue
- advanced training does not improve our knowledge of construction for military operations
- training is focused on maintain instead of building
- for engineers there is a significant void that needs to be addressed
- training needs to be funded and mandated
- the Air Force considers engineers experts after a training class and a couple of projects versus years of experience a civilian engineers takes to become an expert

Although training is a fundamental and necessary action for civil engineers, it was not the primary focus of this research. This question will be further discussed in the conclusion for possible future research opportunities.

The second question of this section's analysis was: "Are there other vertical contingency construction systems or methods that may be needed in the USAF? Please elaborate." For this question, 71% (10 of 14) of the SME's answered yes, with 3 answering no, and 1 did not answer the question. Based on the 10 SME's answer of yes, some other methods they mentioned the USAF may need are:

- replace existing technology
- get with outside agencies on what methods they are using
- Concrete masonry unit
- cast-in-place
- Large Area Maintenance Shelter (LAMS)/tension fabric structures
- insulated concrete forms (ICF)
- low tech solutions
- foldable/relocatable PEB's
- look at/bringing back SEA huts/B huts.

The 2 SME's that answered no had the following explanations: "we are already stretching ourselves too thin with the UBM's, PEBs, and FrameCAD construction, keep it simple, we work in a career field where continuity is important, and making processes easy ensures the ability to construct in any type of contingency environment." With an overall consensus from the SME's on possibly adding other methods to the USAF's contingency construction assets or methods, it was not necessary for this research to ask any other additional

questions in the next round. This question does lend to a possibility of other research and will be discussed further in the final chapter.

4.2.6 Research Questions - Round 1 Summary.

With 3 of the 10 questions of Round 1 reaching consensus, the second round of questions for this Delphi study will focus on the other 7 questions not reaching consensus. Based on the SME's answers in round 1, the researcher realized that the pros/cons question analyzing each system should have been broken into two questions. Therefore, this research will expand the pros/cons analysis into 2 different questions in the second round. This allows for the SME's to focus on each of the systems respective pros and cons and the consolidated answers and themes they provided.

Overall, the first round of questions established the following:

1. Gained consensus from the SME's on UBM being the "best" general contingency construction method
2. Asked about existing contingency construction systems/methods pros, cons, and challenges
3. Gained consensus about the need for more/better USAF contingency construction training
4. Gained consensus that additional contingency construction method's may be valueable

The second round of this Delphi study will focus on the remaining items:

1. The overall challenges of contingency construction
2. Further examining existing contingency construction methods/system's pros, cons, and challenges

4.3 Research Questions - Round 2

Using the analysis conducted in Round 1 of this Delphi study, the second round of questions were generated in order to reach a consensus among the SMEs. The email sent out to the 14 respondents and SME's (from the first round) for the second round can be seen in Appendix C. Using the same type of Adobe form as the first round, the second round of questions used the exact same definition of contingency construction and also incorporated the SME's answers/themes into the new set of questions. The Adobe form created allowed each of the SME's to answer the new questions and explain any of their respective answers. The second round's questionnaire can be seen in Appendix D.

The first question of Round 2 was to present the themes generated from Round 1's question: "What are the top 3 USAFs contingency construction challenges? Please elaborate." Using the theme's given, materials, personnel, and equipment, each was defined within the new question based on the SME's answer in Round 1. The new question in Round 2 is as follows and is based off the same definitions of contingency construction as Round 1:

- Using the above definitions and based on your individual experiences and expertise, the top 3 USAF Contingency Construction Challenges reported were:
- #1 Materials (due to poor procurement timelines and/or quality)
- #2 Personnel (due to right amount and/or lack of expertise or training)
- #3 Equipment (due to the logistics/timing of moving it and/or having the right pieces available)
- Do you agree with these challenges and are they in the right order?
- If you could insert an additional challenge, what would it be?

The next set of questions in Round 2 were to gain consensus on the pros, cons and challenges for UBM/K-Span Construction, PEB construction, and the FrameCAD system. The following statement was used to remind the SME's in what context they should answer these follow-up questions: "The following questions should be based on your personal experiences and expertise, and are follow-up questions from the first round. If you have not worked with a particular system, please try to answer to the best of your ability." In order to individually evaluate each method or system based on the SME's answers from the first round, the following questions were asked in order to gain possible consensus:

Regarding UBM and K-Span Construction:

1. The Top 4 pros of using the UBM reported were: 1) Speed (based on how fast a UBM facility can be built) 2) Transportability (based on the maneuverability of the UBM) 3) Simplicity (based on the minimal engineering effort needed and/or designs) 4) Space (based on the ability to change dimensions or vary sizes per customer requirements). Do you agree with these UBM Pros? Explain.
2. The Top 3 cons of using the UBM reported were: 1) Customization (based on a limited amount of designs) 2) Space (based on the ability to change dimensions or vary sizes per customer requirements) 3) Personnel (based on the amount of personnel needed to support the UBM construction effort). Do you agree with these UBM Cons? Explain.
3. The Top 4 unique challenges of using the UBM reported were: 1) Equipment (due to equipment needed ie crane and/or there only being one UBM available) 2) Materials (due to various products available and their respective logistics and/or steel availability) 3) Personnel (based on the amount of people needed to carry each steel arch and/or personnel trained on the UBM) 4) Training (due to limited amount of training on the UBM) Do you agree with these UBM Challenges? Explain.

Regarding Pre-Engineered Buildings:

1. The Top 2 Pros of using the PEB method reported were: 1) Customizable (based on the ability to customize floor plan and designs for each project) 2) Permanent (based on the life span of PEBs) Do you agree with these PEB Pros? Explain.
2. The Top 4 Cons of using the PEB method reported were: 1) Logistics (based on the long procurement timelines/process and/or delivery) 2) Cost (due to the cost of using a contractor for designs/procurement of the building) 3) Equipment (based on the specific equipment needed for construction) 4) Foundation (based on the foundation/columns needing to be accurate/precise and/or the time this takes) Do you agree with these PEB Cons? Explain.
3. The Top 2 Challenges of using PEBs reported were: 1) Logistics (based on the time required for design, manufacturing, and delivery of the PEB) 2) Foundation (based on placing the foundation footers or columns correctly and/or the time this takes) Do you agree with these PEB Challenges? Explain.

Regarding the FrameCAD system:

1. The Top 3 Pros of using FrameCAD reported were: 1) Adaptability (based on the ability to be tailored to user requirements and/or anything can be designed) 2) Simplicity (based on the ease of use between the software and hardware and/or the actual construction) 3) Speed (due to how fast the machine can produce an entire building) Do you agree with these FrameCAD Pros? Explain.
2. The Top 3 Cons of using FrameCAD reported were: 1) Cost (due to the initial costs, re-occurring costs, replacement parts cost, and/or licensing) 2) Software (based on the software not working well with other software and/or annual renewals) 3) Training (due to minimal personnel being trained on the FrameCAD system) Do you agree with these FrameCAD Cons? Explain.

3. The Top 2 Challenges of using FrameCAD reported were: 1) Maintenance (meaning that the machine needs regular maintenance and/or repair kits) 2) New (due to the FrameCAD system not being an official UTC and/or it being a new technology to the USAF) Do you agree with these FrameCAD Challenges? Explain.

4.4 Round 2 Analysis

This second round of questions was emailed out to the 14 SME's from the first round, 2 weeks were given for the SME's to respond, and 11 ended up sending in their responses by the deadline. With 3 of the original SME's not responding in this second round, the rank breakout was: 3 Majors, 4 Captains, 3 Technical Sergeants, and 1 Master Sergeant. Additionally, 3 of the SME's that answered during this round did not qualify as SME's for the FrameCAD system. All 11 respondent's of this round did qualify as SME's for both the UBM/K-Span construction and PEB construction.

The following paragraphs will analyze the answers provided by the 11 SME's that answered the second round of questions. Reaching consensus among the SME's is the goal of each of these questions along with providing the CE community and contingency construction experts a holistic view of what the current pros, cons, and challenges are for the USAF's current assets and contingency construction methods.

4.4.1 Round 2 - Section 1 Analysis - Top Contingency Construction Challenges.

In order to gain consensus among the 11 SME's that participated in this round, the most common themes from all the SME's answers in the first round of questions were used. The common themes provided for the USAF's top contingency construction challenges were: materials, personnel, and equipment. Out of the 11 SME's that responded, 100% of them agreed to this list of challenges for contingency construction. Two of the SME's also commented that personnel and equipment could be interchangeable and another SME commented that they all could fluctuate in order of importance. Some of the SME's offered a fourth or additional challenge such as: weather conditions, schedule creep, host

nation coordination, logistics, designs, planning, and funding. Overall, these 3 challenges provided by the SME's of contingency construction achieved consensus in the second round of questions in this Delphi study.

4.4.2 Round 2 - Section 2 Analysis - UBM.

In the first round of questions of this Delphi study, there were 2 questions that asked about the 'pros and cons' and challenges of the UBM/K-Span construction method. In this second round, those 2 questions were split into 3 questions in order to separate the pros and cons for analysis and consensus purposes. All 11 of the SME's qualified as UBM/K-Span experts and the answers from the first round of questions were used to develop the second round of questions.

4.4.2.1 UBM Pros.

The first question analyzing the UBM/K-Span construction asked the SME's to agree or disagree with the 4 reported pros from the first round of answers. The Top 4 pros were: speed, transportability, simplicity, and space. Each of these themes were defined and the definitions can be seen in the "Research Questions - Round 2" section. After analyzing the answers, 100% of the SME's agreed that these were the top 4 pros of using the UBM, thus providing consensus.

Although 11 SME's did agree with top 4 pros reported, many of them did not fully agree, but each explained in the comments with their respective rationale or thoughts. For example, one SME explained that he/she was "not convinced that a k-span is faster to construct from concept to facility turnover due to material issues." Another SME commented that materials should be added due to the "basic structure of a k-span is only steel, concrete, rebar, and dowels" which are not specific to the building and can be kept on hand, ready for the next emergency structure needed. Similar to this comment, another SME mentioned that "the biggest advantage of the K-Spans is the flexibility of having the

bench-stocked materials (coils of steel)” and would include that in the speed (or logistics) category.

4.4.2.2 UBM Cons.

The second question analyzing the UBM/K-Span construction asked the SME’s to agree or disagree with the top 3 reported cons of using the UBM. The top 3 cons reported by the SME’s were customization, space, and personnel. Each of these cons reported were defined based on the SME’s answers and can be seen in the “Research Questions - Round 2” section. Due to only 54% of the SME’s agreeing with these cons, this question did not reach consensus. This question was the least agreed upon among all of the questions in the second round of this Delphi study. Some of the SME’s objections for this question are highlighted below.

One SME mentioned that he “disagrees with personnel being a con, just by sheer numbers, as in my experience a K-span takes less personnel than a PEB.” Another SME stated that he “wouldn’t agree on the customization being a con because I think you can vary your designs with your height, width, and the fact that your length can be customized to the requester needs for a facility.” Similar to the last comment, another SME said “not sure how space is a con....agree more with having it up above as a pro...you can easily alter the width and build it as long or as short as you want...I think the con is that once constructed, it is difficult to retrofit or renovate.” Finally, another SME disagreed with customization and stated it “is a problem, since you’re effectively limited based on the machine, software, and materials (i.e., you’re constrained to certain shapes/geometries).”

Although this question did have the most debatable results, 6 of the SME’s did agree with the order and definitions of these UBM cons. One of the SME’s stated “cons are spot on” and “need to make sure personnel are properly training, particularly RED HORSE.” Similar to these other SME’s comment, one SME agreed with the cons, but also offered to add training “due to the difference between the 240 and 120 K-Spans...from my experience

the 240 requires nearly double the amount of personnel due to the greater size and much heavier operations than the 120.” Another SME agreed, but also stated “the main reason K-Spans are not used in many cases comes down to design/aesthetics and the issue is that many bases (including in the AOR) will not accept a K-Span as it just doesn’t match the shape/style of their typical PEB steel/CMU buildings.” Another SME mentioned that the personnel requirement should be the top issue due to “requiring specialized training and calibration...the manpower required to safely transport the individual arches dictates that either skilled craftsmen must be pulled from another task or a source of un-skilled labor must be available...a crane and competent operator must be available to install the individual Picks.” “Picks” is a slang construction term used to describe multiple steel K-Span arches that are seamed together and that are ready to be lifted into place.

4.4.2.3 UBM Challenges.

The third question analyzing the UBM/K-Span method asked the SME’s to agree or disagree with the top 4 unique challenges of using the UBM. The top 4 unique challenges of using the UBM reported from the first round of questions were equipment, materials, personnel, and training. Each of these unique challenges reported were defined based on the SME’s answers from the first round of questions and can be seen in the “Research Questions - Round 2” section. Out of the 11 SME’s that participated in the second round of questions, 90% them agreed to the provided challenges, thus providing a consensus on this question.

The one SME that did not agree to the unique challenges, did however, agree that materials, personnel, and training were unique, but did not think equipment was a unique challenge due to “customers in CONUS don’t typically want k-spans, which makes training difficult and limits material suppliers.” Five of the SME’s did not have any comments at all for this question. A few additional challenges were proposed by the SME’s that included space and planning/leadership. One SME also thought that training and personnel

challenges should be reversed, due to “given other project requirements, the team size needed for a k-span, specifically steel work is less an issue than training on UBM’s.”

4.4.3 Round 2 - Section 3 Analysis - PEB.

In the first round of questions of this Delphi study, there were 2 questions that asked about the ‘pros and cons’ and challenges of the PEB construction method. In this second round, those 2 questions were split into 3 questions in order to separate the pros and cons for analysis and consensus purposes. All 11 of the SME’s in Round 2 qualified as PEB experts and the answers from the first round of questions were used to develop the second round of questions.

4.4.3.1 PEB Pros.

The first question analyzing the PEB construction method asked the SME’s to agree or disagree with the 2 reported pros from the first round of questions and answers. The top 2 pros were customizable and permanent. Each of these PEB construction method pro themes were defined and the definitions can be seen in the “Research Questions - Round 2” section. Based on their answers, 100% of the SME’s agreed that these were the top 2 Pros of using the PEB method, thus providing consensus.

Five out of the 11 SME’s did not provide any comments to this question. Out of the 6 SME’s that did comment on this question, one of the SME’s stated that “as part of the customizable benefit, it can be more structurally stable during seismic, wind, and/or snow events...at least it can be designed to have a higher structural capacity during such events.” Similar to this comment, another SME said he would “add that PEBs are designed by licensed engineers, who design PEBs for a living...it reduces the risk of a structural issue considerably...PEBs also provide for multi-story and large clear span construction.”

4.4.3.2 PEB Cons.

The second question analyzing the PEB construction method asked the SME’s to agree or disagree with the top 4 reported cons from the first round of questions and answers. The

top 4 cons reported were logistics, cost, equipment, and foundation. Each of these PEB construction method con themes were defined and can be seen in the “Research Questions - Round 2” section. Based on the SME’s answers to the PEB cons question, 90% agreed that these were the top 4 cons of using the PEB method, thus providing consensus.

Three out of the 11 SME’s did not provide any comments to this question. Out of the 7 SME’s that did comment and agreed, one of the SME’s said “even with the four cons listed I believe the PEB is still the best choice right now for construction.” Another SME stated that “PEBs do take longer during both planning and execution, but you get a longer term, higher quality product...however, this may not be needed for a typical contingency effort...I think that the military (particularly the Air Force) needs to redefine contingency...we are building too many permanent structures in the AOR.” A separate SME said that he agreed “that the largest issue with the PEB is the logistics.. All of the other issues can be addressed, however the logistical obstacles are outside of the Air Force’s realm of control...the required time to design and manufacture the steel is set by the industry.” Finally, the one SME that disagreed with this list of cons stated “I don’t agree with the cost being one of the cons, because its standard procedure when purchasing a PEB to having a contractor design/make the PEB...I think it is a positive to have the company send you the designs beforehand so you can verify and or dispute that certain things are right or wrong so they can be fixed before the PEB is manufactured to your needs.”

4.4.3.3 PEB Challenges.

The third question analyzing the PEB construction method asked the SME’s to agree or disagree with the top 2 reported challenges from the first round of questions and answers. The top 2 challenges reported were logistics and foundation, both of which were also reported as cons. Each of these PEB construction method challenge themes were defined and can seen in the “Research Questions - Round 2” section. After analyzing each of the

SME's answer for this question, 100% agreed upon these top 2 reported challenges, thus providing consensus for this question.

Eight out of the 11 SME's did have comments for this question. One SME stated that "the foundation should not be a problem if you have the right personnel...so I'd chalk that up to training as the actual challenge...Logistics (to include coordinating designs with the PEB manufacturer) and materials are still the number one challenge." Another SME agreed with this statement by saying "with the logistics side I would also add the time it has been sitting on the ground from the delivery to construction time...since the longer it has been sitting there, there is more potential for parts/screws/nuts and bolts to get lost, used on different building/project, or get misplaced or moved numerous times before construction is a big factor in the logistics." Another SME agreed with both reported issues, but mentioned that this survey focuses heavily on the craftsmen aspect of contingency construction, "but our engineers also play a large role in PEB on the design side...PEBs are considered permanent construction (i.e., higher level of standard) and often require foundation designs, both of which are typically not taught to our engineers." Another SME also agreed, but thought the "key challenge is managing missions, aesthetics, and customer expectations in the AOR...it seems that everyone in AFCENT wants a PEB, but sometimes a K-Span can do the job much quicker/cheaper...also understanding of what RED HORSE/Prime BEEF contingency capabilities in the AOR is limited...many of the large PEBs (i.e. permanent DFACs) exceed USAF Troop Labor primary capabilities."

4.4.4 Round 2 - Section 3 Analysis - FrameCAD.

In the first round of questions of this Delphi study, there were 2 questions that asked about the 'pros and cons' and challenges of the FrameCAD system. In this second round, those 2 questions were split into 3 questions in order to separate the pros and cons for analysis and consensus purposes. Only 8 of the 11 SME's qualified as FrameCAD experts based on there answers to the demographics questions. The answers and explanations from

the first round of questions were used to develop this second round of questions analyzing the FrameCAD system.

4.4.4.1 *FrameCAD Pros.*

The first question analyzing the FrameCAD system asked the SME's to agree or disagree with the top 3 reported pros from the first round of questions and answers. The top 3 pros were adaptability, simplicity, and speed. Each of these FrameCAD system pro themes were defined based on the SME's answers from the first round of questions and the definitions can be seen in the "Research Questions - Round 2" section. After analyzing the SME's answers, 100% agreed that these were the top 3 pros of using the FrameCAD system, thus providing consensus.

Only 5 of the 8 SME's commented on this question. One SME agreed, but "would also include the flexibility of having the bench-stocked materials (coils of steel)...I would include that in the Speed (or a Logistics) category." Another SME said that "being a new construction method used in the Air Force the FrameCad is a great asset to have but it is not used to it's full potential." One SME commented and about training and how specialized FrameCAD really is by saying "this is all based on training that is currently very limited and specialized...also, if it's just a metal stud building, you can only adapt it so much (i.e. I don't think you can build a big aircraft hangar with large bays using FrameCAD)." Another SME added that these pros is "where the FrameCAD or similar systems surpass the PEBs and K-Spans...unlike the other two systems, FrameCAD is universal for both exterior and interior framing without the need of additional resource planning throughout both phases of construction...speed on this one is also slightly dependent upon the exterior sheathing method as well."

4.4.4.2 *FrameCAD Cons.*

The second question analyzing the FrameCAD system asked the SME's to agree or disagree with the top 3 reported cons from the first round of questions and answers. The

top 3 cons were cost, software, and training. Each of these FrameCAD system con themes were defined and the definitions can be seen in the “Research Questions - Round 2” section. According to the answer’s provided by the SME’s, 100% agreed that these were the top 3 cons of using the FrameCAD system, thus providing consensus.

Five of the 8 SME’s also had comments for this question. One SME stated that “the yearly software updates and not having the proper training on the machine/design software limits the potential of using the machine.” Another SME commented on the availability of the FrameCAD in a contingency environment by saying “it’s a very specialized system right now and not many people know about it...the lack of availability/training/material makes it a non-asset in the AOR.” Another SME mentioned adding a fourth con, transportation, because “moving the FrameCad machine and container great distances away is Con as well...its due to the fact transportation of the 40’ long trailer it is kept in, would be a transportation nightmare unless it going to be kept in one central location.” Another SME simply said, “we need the time to train and use the system.” Finally, a SME addressed the cost and software con directly by stating “I would put the software concern at the bottom of the list because FrameCAD has been pushing out updated software that is “supposed” to be more compatible with other programs...they have expressed interest in providing multi-year licensing agreements that could be negotiated at an AF wide level if the system gains enough support and momentum.”

4.4.4.3 FrameCAD Challenges.

The third question analyzing the FrameCAD system asked the SME’s to agree or disagree with the top 2 reported challenges from the first round of questions and answers. The top 2 challenges reported were maintenance and new. Each of these FrameCAD system challenge themes were defined and the definitions can be seen in the “Research Questions - Round 2” section. Much lower than both the pros and challenges questions, only 62% of

the SME's agreed that these were the top 2 Pros of using the FrameCAD system, but still met the threshold for providing consensus.

Out of the 3 SME's that did not agree completely with these challenges, one said that "not sure I completely agree with maintenance as one of the top challenges...the maintenance required for FrameCAD was much less than that required for UBM machines." Another SME that disagreed stated that "I agree with the maintenance challenge but not it being new...just like any other machine it needs scheduled maintenance and replace parts but it doesn't break as easily as other machines would...the machine being new would not be a challenge because with the proper training it being new should not matter when it comes to the operation of the machine." The last SME disagreed with maintenance and said "just like any piece of equipment ie. the UBM, welding machines, or anything else it requires maintenance to keep it running at optimal levels...however, I have received formal training on the maintenance of both UBMs and FrameCAD and find the FrameCAD easier to troubleshoot and repair."

Although 5 SME's did agree with the FrameCAD challenges, only 4 of them commented. One SME stated that the FrameCAD is "even more specialized than the UBM so if something breaks, it could be hard broken for a while...also, no one knows about it." Another SME commented on the maintenance challenge and stated that "part of these problems are also due to the fact that there is only one FrameCAD location serving Europe and the Middle East to reach out for the training/helping with the maintenance." Another SME discussed how to combat these challenges and said the "#1 challenge is the need to deploy at least 2 FrameCAD systems to the AOR, plus backup parts and software, in order to reach IOC for this method...until that is done, FrameCAD will only be experimental for the USAF." Finally, another SME commented on the new challenge and said "the largest hurdle is that this system is new...the other systems have been around for a long time and there are still difficulties in retaining experienced personnel to operate and design

for them...the FrameCAD system will have to gain significant support in order to carve out a place in the Air Force's toolbox.”

4.4.5 Research Questions Round 2 - Summary.

Overall, the second round of questions analyzed the individual pros, cons, and challenges of the UBM/K-Span method, the PEB method, and the FrameCAD system. Although 11 of the SME's qualified as experts for both the UBM/K-Span Construction and the PEB method, only 8 qualified for the FrameCAD system based on previously answered demographics from the first round of this Delphi study. Based on the SME's answers for the second round of questions of this Delphi study, consensus was achieved for all of the systems/methods proposed pros, cons, and challenges, except the UBM cons themes. Because consensus was achieved for most areas of interest, a third round of questions was not necessary for this study.

4.5 Results and Discussion Summary

A Delphi study explored the pros, cons, and challenges of contingency construction methods/assets. After two rounds of the Delphi study, consensus was almost fully reached for all questions asked based on the contingency construction SME's inputs. It is of note that the SME's were not asked to evaluate each of the pros/cons/challenges themes individually, but were asked to evaluate and answer based on them being a group. A combined visual representation of the pros, cons, and challenges of each system/method can be seen in Table 4.14. The color schemes shown in Table 4.14 represents the different levels of consensus achieved in the Delphi Study. Green represents consensus in the range of 80-100%. Yellow represents consensus in the range of 60-80%. Finally, blue represents the themes that did not reach consensus, or that fell below the 60% threshold of agreeing by the SME's.

In the final chapter of this thesis, the researcher summarizes the basis of this research, the literature and systems review, the methodology, the analysis, and highlights future

potential research related to contingency construction. In addition to an overview of the previous chapters, the conclusion will discuss the benefits and meaning of this research to the RED HORSE and Civil Engineer community. The conclusion will also propose where to add these contingency construction methods/systems overviews into USAF literature for the benefit of civil engineer personnel.

Table 4.14: Systems Summary - Pros, Cons, and Challenges

<u>System/Method</u>	<u>Pros</u>	<u>Cons</u>	<u>Challenges</u>
UBM	Speed	Customization	Equipment
	Transportable	Space	Materials
	Simplicity	Personnel	Personnel
	Space		Training
PEB	Customizable	Logistics	Logistics
	Permanent	Cost	Foundation
		Equipment	
		Foundation	
FrameCAD	Adaptable	Cost	Maintenance
	Simplicity	Software	New
	Speed	Training	

V. CONCLUSION

IN the previous chapter, the presentation and analysis of the two rounds of the Delphi study have been reported. This chapter consists of a general overview of the study, discussion of the findings, recommendations for possible future research, suggested additions to USAF guidance, and conclusions. The purpose of the next sections is to summarize and expand upon the contingency construction systems/methods analyzed, and to provide possibilities for research that deals with USAF construction, RED HORSE, and contingency construction. Finally, the conclusion section discusses the overall value and implications of the researcher and SME's input on the topic of vertical contingency construction systems/methods.

5.1 Summary of the Research

This research recognized a need to compare and evaluate the existing RED HORSE contingency construction methods/systems. RED HORSE has existed for over 50 years, currently has 4 active duty squadrons, and is currently employed overseas in multiple military contingency environments. The researcher took site visits to two of the RED HORSE locations, discussed the nature of this research, and gained contacts needed to be SME's in the Delphi study. The site visits established that the UBM/K-Span construction method, the PEB method, and the FrameCAD system are the only current relevant systems/assets in use by RED HORSE at the time of this research. Other construction techniques were briefly discussed in the literature review and may be sparingly used at some, but not all, of the RED HORSE units.

The purpose of this research was to quantify which existing RED HORSE contingency construction method or asset was "best" and the pros/cons/challenges associated with each system using a panel of contingency construction SME's. Fourteen SME's participated in

the first round of the Delphi study, and 11 (of the original 14) SME's participated in the second round of the Delphi study. Based on the 2 rounds of 10 questions for this Delphi study, the research established consensus on pros, cons, and challenges of each contingency construction methods/systems, except the UBM's cons. The Delphi study also reached consensus on which system/method is "best" for contingency construction. Additionally, the Delphi study asked the SME's about the limitations of contingency construction, if the USAF provides enough training for vertical contingency construction, and what other vertical contingency construction assets/methods may be needed.

5.2 Key Findings

Based on the literature and systems review research done, the researcher did not have initial inclinations on which contingency construction system/method would be best or most preferred by the SME's. The FrameCAD system was known to be the newest system, but also showed great potential for contingency construction capabilities although less empirical evidence for such use exists to date. Both the UBM/K-Span construction method and the PEB method were known to be used and proven methods employed by RED HORSE. Getting the opinions of SME's that have been deployed to contingency environments, were part of RED HORSE units, and have used each of these construction systems/methods was critical to this research.

In order to harness the collective thoughts of a group of contingency construction experts, the research decided to use the Delphi method. The questions generated for the panel of contingency construction experts was based on the literature and systems review of contingency construction, site visit to AFCEC, Silver Flag, and 2 RED HORSE units, and the previous experiences of the researcher while employed by RED HORSE. The researcher's intent was to lead the panel of SME's toward consensus for each of the questions asked in each round of the Delphi study.

The first round of the Delphi study gained consensus for 3 out of the 10 questions asked. The SME's established that the UBM/K-Span construction method is the "best" contingency construction method based on this research's definitions, that the USAF does not currently provide enough training for vertical contingency construction, and other contingency construction assets/methods may be needed for the USAF. Although UBM was reported as the "best" contingency construction method by the SME's, bias could be seen in this answer since all of the SME's had experience in UBM, but not necessarily in all of the systems/methods being evaluated. Based on this bias, this research cannot report in confidence that UBM is truly the "best" contingency construction method.

The second round of the Delphi study analyzed the responses of the 7 remaining questions from the first round of questions that did not reach consensus. These 7 questions were expanded into 10 questions for the second round of the Delphi study. After these questions were presented to the SME's, and based on their respective responses, the researcher decided that consensus was achieved for each of the questions and information presented, except for the UBM/K-span con themes question. The second round of questions reached consensus on the key challenges of USAF contingency construction and the pros, cons, and challenges of the UBM/K-Span construction method, the PEB method, and the FrameCAD system. Due to consensus being achieved for almost all of the information presented to the SME's in the second round of the Delphi study, a third round of questions was not needed nor provided to the SME's. A summary of the findings for each of the contingency construction systems/methods was presented at the end of chapter 4 and can be seen in Table 4.14 which highlights the pros, cons, and challenges provided and agreed upon by the SME's in this study.

5.3 Research Impacts

The performance criteria of the contingency construction systems/methods was presented in chapter 2 and the SME's (without being asked directly) also provided an

explanation of why each of the systems/methods being analyzed were preferred or not. For RED HORSE personnel and engineering personnel in contingency environments, each of these systems provide a distinct solution in different situations or environments. The following paragraphs highlight each systems/methods impact to contingency construction.

Based on this thesis' research and analysis, the UBM/K-span construction method is ideal for customers/engineers who need a facility for generic storage space. If the 240 UBM is available, it could be argued that a facility could even be built for certain aircraft's storage. Additionally, UBM/K-spans could be built relatively quickly if rolled steel and concrete are on-hand/available. The UBM is also easily transportable, which makes this an asset ideal for most contingency environments. The steel K-spans built could serve a variety of other purposes rather than just storage such as a dining facility, vehicle bay, small aircraft hangar, personnel gathering area, or personnel sleeping facilities. Based on some of the SME's responses, the USAF would likely use and build more K-spans if architectural and aesthetic standards were not such an issue. Overall, the UBM/K-span method will continue to provide a viable impact to future contingency construction efforts.

Similar to the UBM, the FrameCAD has immense potential to serve in contingency construction environments. A few of the SME's suggested ways to implement the FrameCAD into CENTCOM's construction arsenal. The FrameCAD asset, with steel and concrete available, could also quickly build storage or office spaces in almost any contingency environment. The FrameCAD asset is currently not as transportable as the UBM, but changes to the current setup may be possible if the USAF were to buy more of the FrameCAD. Another advantage of the FrameCAD is that it could possibly replicate many of the standard wooden structures and engineers could build those known facilities in record time using this new asset. The FrameCAD also provides many of the architectural and aesthetic standards that the UBM system does not, which could increase its use in stateside and/or contingency locations. In summary, the FrameCAD could modernize and

expedite construction in many construction environments that the USAF currently operates in.

The PEB method was suggested by SME's to be the most structurally sound and multi-purpose construction method RED HORSE uses. If time is not of importance and customers need more specialized facilities, the PEB construction method would be ideal. Additionally, if organic engineers are not available to design and plan a new facility, awarding the project to a contractor and letting them design, build, and deliver the PEB is a huge advantage. Using this extra time, the downrange engineers could then plan and acquire the necessary Airmen to construct the PEB once it is delivered. Another advantage of the PEB is that no actual materials are needed to be sought by the engineers, and that burden falls completely on the contractor responsible. Although no materials are needed, the equipment necessary to construct the PEB would have to be acquired and mobilized once the PEB arrives. Overall, the PEB method has extensive uses in all contingency construction environments and will continue to provide solid multi-use facilities.

Even with a biased response from the SME's as UBM being reported as the "best" contingency construction method, engineers must critically think through their respective contingency construction environment and choose the right asset/method for their situation. Each of the systems/methods analyzed and discussed could serve a purpose in contingency construction environments. Speed, size of the facilities, logistics support, availability of engineers and Airmen, and the environment would all be applicable factors in the engineer's or commander decision making process for which system/method to choose. It is also imperative to note, that based on this research these systems/methods could meet the intent of the USAF's strategic intent in "modernizing capabilities while reducing operating costs"[11]. Each of these systems/methods could also have an impact in creating a "lighter, leaner, and more resilient contingency equipment and installations" as stated in the CEFPP [10].

5.4 Future Research Potential

The researcher realized many different avenues of possible future research relating to contingency construction while on site visits, during conversations with users, multiple email conversations, and discussions with AFCEC research personnel. The following subsections will quickly discuss and summarize some possible avenues of research that could follow on this research.

5.4.1 Training.

During the first round of the Delphi study, the SME's reached consensus and almost all agreed that the USAF needs additional training for vertical contingency construction. Based on the consensus received, future research could include how long existing training is, what the training entails, who attends the training, and how the training is implemented at each RED HORSE location. Before this research focus began, the researcher discussed the implications of certain timelines of training with AFCEC personnel and whether the current standards were enough for our missions. Future research could also compare the amount of training need to become an "expert" on the civilian/commercial side for general or contingency construction practices. This research could also work with the Civil Engineer School, based at Wright Patterson AFB, which conducts the primary means of educating civil engineer personnel across a wide range of topics relating to the career field and mission needs. A final thought to this potential training research topic could be to analyze if the USAF is actually training on too many things for personnel to actually efficiently retain and remember effectively.

5.4.2 Costs.

The costs of each of the contingency construction systems/methods was not thoroughly analyzed or researched as part of this thesis. Future research could look into the direct and indirect costs of each system/method. This could entail the costs of initial purchase, software licenses, license renewals, annual maintenance, personnel training,

reoccurring training, emergency maintenance, logistics, materials, maintenance kits, and/or other costs that affect each of these systems/methods. Using these respective costs, a researcher could do a value-engineering analysis for each of these systems/methods or other new systems/methods and present the findings to RED HORSE personnel and leadership.

5.4.3 Logistics.

Similar to the potential of analyzing the costs of contingency construction assets/methods, research could be conducted on what the logistics of using each of these construction systems/methods actually looks like in a contingency environment. Conversely, research could also be conducted on how to implement a new contingency construction system/method (like FrameCAD) effectively at a contingency location. The research would need to evaluate costs, travel methods, materials needed, locations, system or user needs, and construction potential of the system or method evaluated.

5.4.4 Designs.

A more technical focused researcher could develop possible designs and solutions for each of the contingency construction systems methods presented in this research. The FrameCAD system shows immense potential based on the SME's comments, but the designs were not evaluated in this study. Many of the wooden construction designs of buildings could be integrated into standardized designs for the FrameCAD system, which then could be used for extremely quick construction in different contingency environments. Potential research could also look at current USAF contingency construction standards and evaluate what or how these standards could be implemented effectively into the FrameCAD systems building designs. This would be a collaborative effort with AFCEC staff, EA's, and RED HORSE engineering flight.

5.4.5 Horizontal Contingency Construction Methods.

This research only focused on the vertical construction that RED HORSE currently employs across the globe. Future research could look into asphalt, concrete, or other

horizontal construction techniques/methods/assets. Each of these systems or methods could be evaluated, and their may be much more current and previous research to base a thesis off of in this topic. A researcher could also look into all the specific equipment needed for military horizontal construction and compare it to the equipment needed for civilian/contractor horizontal construction. This potential research could also look into different asphalt or concrete designs and has a huge array of other research potential. The researcher could work with AFCEC's pavement team and staff at the Civil Engineer School.

5.4.6 Other Possible Construction Methods or Systems.

As consensus was achieved by the SME's for the USAF possibly needing other contingency construction methods or assets, future research could bolster the USAF's knowledge on these known and unknown systems/methods. The SME's did identify multiple systems and avenues that they actually had experience in and/or recommended that the USAF adopt such as Concrete (including cast-in-place, tilt-up, and pre-cast), timber frame or wood, CMU, stress-tensioned fabric, insulated concrete forms, low tech solutions, and foldable/relocatable PEBs. These respective systems or methods could be evaluated similarly to this study or through other research methods. The findings of this potential research could then be presented to AFCEC, RED HORSE, and Civil Engineer leadership for possible implementation.

5.5 Research Implementation

As was initially discussed in the beginning of this thesis, this research has a potential to be added to existing USAF literature. In the (Unclassified) Civil Engineer Supplement to the War and Mobilization Plan-1, there is no mention of assets that can rapidly create and construct facilities. This war and mobilization plan states that, "the most primary requisite of construction in wartime is speed"[12]. In section 3.1 or 3.2 of the war and mobilization plan, additional guidance and verbiage could be added that addresses the capabilities of

RED HORSE Airmen using either the UBM or FrameCAD assets, since both are mobile assets and have the possibility of being built with extreme speed [12].

As the “Sand Book” is known as an Engineer’s go-to guide for contingency and Joint operations construction planning, there is no section or appendix that addresses possible construction systems/methods directly [28]. A summary of this research, other construction systems/assets, Joint construction methods, and/or other construction methods could be synthesized and added as an appendix. This additional appendix would give Joint engineers a better idea of the organic construction asset possibilities that the DOD and USAF already have.

5.6 Research Conclusion

This research initially reported that the UBM/K-Span method is currently the “best” contingency construction asset/method based on the answers of contingency construction SME’s, but due to the bias experience levels of the SME’s, it cannot be reported that the UBM/K-Span method is truly the “best” unless all the SME’s had the same level of experiences on each method/system. Additionally, the SME’s reported and agreed that the USAF’s top contingency construction challenges were materials, personnel, and equipment.

This research also developed pros, cons, and challenges for the three primary systems/methods in use by RED HORSE. The UBM/K-Span construction method’s pros were speed, transportability, simplicity, and space. The cons of using the UBM/K-Span construction were customization, space, and personnel, but these themes did not reach a consensus from the SME’s in this research. The challenges of using the UBM/K-Span method are equipment, materials, personnel, and training.

The PEB construction method’s pros are customizable and permanent. The cons of using the PEB method are logistics, costs, equipment, and foundation. The challenges of using the PEB method are logistics and foundation.

The FrameCAD system, one of the most recent construction asset acquisitions of RED HORSE, pros are adaptability, simplicity, and speed. The FrameCAD system's cons are cost, software, and training. The FrameCAD system's challenges are maintenance and new.

Based on this research's analysis and findings, this research will inform Civil Engineers and RED HORSE personnel across the Air Force. Contingency construction is critical to the Civil Engineers mission, and having SME's provide opinions and research that analyzes and presents the findings is imperative to continuous education and knowledge of this career field. The goal of this research was to also provide a baseline of information for Civil Engineering personnel that may not know about the USAF's current contingency construction assets/methods and their respective pros, cons, and challenges. Although it was not heavily focused on in this research, it was also found that the USAF may need additional contingency construction training and that other construction methods/systems could or should be added to the USAF's inventory.

Appendix A: Round 1 Email

AFIT Research: Evaluation of Contingency Construction Methods (Response Requested by 3 NOV 17)



Bentley, William E Maj USAF AETC AFIT/ENV

Fri 10/20/2017, 3:15 PM

Langhals, Brent T Civ USAF AETC AFIT/ENV; Gene Bentley <web007@gmail.com>; Williamson, Jacob <JAWilliamson@HaywardBaker.com>; 8

Reply all | v

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You forwarded this message on 10/26/2017 5:48 PM



Evaluation of Contingen...
69 KB

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BLUF: You have been identified as a potential Air Force Contingency Construction SME. Your response to the attached AFIT research questionnaire is requested by Friday, 3 November 17.

Good Morning/Afternoon,

PURPOSE: You are receiving this email because you have been identified as a potential Subject Matter Expert in the field of Air Force Contingency Construction. I am a CE officer currently enrolled in the Graduate Engineering Management (GEM) program at the Air Force Institute of Technology (AFIT). The focus of this thesis effort is to evaluate the Air Force's current contingency construction methods.

BACKGROUND: Within the 2016 Civil Engineer Flight Plan, line of effort 2.4 states that the USAF needs to "create lighter, leaner, and more resilient contingency equipment and installations." For the purpose of this research, contingency construction is defined as military forces constructing vertical facilities (specifically PEBs, UBM K-Span's, or FrameCAD) at natural disasters, terrorist events, subversive responses, military operations, humanitarian operations, or remote operations. To develop this field of knowledge, the research team is performing a "Delphi Study" in which the research attempts to find consensus amongst SME's through several rounds of surveys. The first survey is attached.

SURVEY INFORMATION: Participation is completely voluntary and you may drop out at any time, with no adverse effects. The questionnaire is 10 questions long and you may write as much or as little as you wish. As you are able, please accomplish the attached survey by 3 November 2017. Further information about the study and questionnaire can be found in the attached survey. This PDF survey has a "Save As" button at the bottom of the form which should work to save your responses and then please email the response via an attachment back to me (william.bentley@afit.edu and web007@gmail.com) at your soonest convenience.

Please let me know if you believe that you have received this email in error. Additionally, if you have any questions or concerns, please let me know. Thank you very much for your time and consideration in this research effort.

V/R,

WILLIAM E. BENTLEY, MAJ, USAF

AFIT/ENV Master's Student

william.bentley@afit.edu and web007@gmail.com

Cell: (870) 904 4120

Appendix B: Round 1 Questionnaire

Air Force Institute of Technology Evaluating Contingency Construction Methods Demographics & Research Questionnaire – Round 1

Purpose: The purpose of this study is to research and analyze the Air Force's contingency construction methods currently being used. For the purpose of this research, contingency construction is defined as military forces constructing vertical facilities (specifically Pre-Engineered Buildings (PEB), Ultimate Building Machine (UBM) K-Span's, or FrameCAD facilities) at natural disasters, terrorist events, subversive responses, military operations, humanitarian operations, or remote operations. The goal of this research is to evaluate and understand each of these construction methods. This research will be conducted via the Delphi Study method, in which the researcher contacts subject matter experts to help develop a consensus of opinion. The researchers will send out subsequent questionnaires to develop and refine expert opinions. At the conclusion of this research effort the researchers intend to publish and present the results, as well as brief those results to Civil Engineer leaders.

Researchers: Dr. Brent Langhals AFIT/ENV, and Maj William Bentley AFIT/ENV.

Disclaimer: As a survey respondent, you have the ability to self-eliminate from participating in any current or future surveys, at any time. No adverse action will be taken against anyone who chooses not to participate in current or future research. Survey responses will be recorded anonymously, and your comments will not be attributable to you when/if the research is published. Your responses will be maintained IAW the Privacy Act Statement of 1974. By filling out and responding to this questionnaire, you are hereby acknowledging and consenting to your participation in this research.

Privacy Act Statement: Your survey response contains FOR OFFICIAL USE ONLY (FOUO) information which must be protected under the Freedom of Information Act (5 U.S.C. 552) and/or the Privacy Act of 1974 (5 U.S.C. 552a). Unauthorized disclosure or misuse of this PERSONAL INFORMATION may result in disciplinary action, criminal and/or civil penalties. Further distribution is prohibited without the approval of the author of this survey unless the recipient has a need to know in the performance of official duties. If you have received this survey in error, please notify the sender and delete all copies of this survey.

Demographics

1. What is your Rank:

2. What is your current Job Title:

3. What is your Air Force Specialty Code?

4. What is your deployment experience – How many? Where? What did you do?

5. How many years of construction experience do you have with the following systems:

- UBM K-Spans

- PEB's

- FrameCAD

- Other Construction Systems (Please List)

Research Questions

This research defines contingency construction as military forces constructing vertical facilities (specifically Pre-Engineered Buildings (PEB), Ultimate Building Machine (UBM) K-Span's, or FrameCAD facilities) at natural disasters, terrorist events, subversive responses, military operations, humanitarian operations, or remote operations. Traditionally, contingency construction has been limited from initial bed down to 2 years, however, this thesis does not limit the contingency timeline and is considered from bed down to base closure, site closure, or mission completion.

1. Using the above definitions and based on your experience and expertise, what do you believe is the “best” contingency construction equipment or method for vertical construction? Why?

2. What are the top 3 USAF's contingency construction challenges? Please elaborate.

Answer the following questions based on your personal knowledge/experience. If you have not worked with a particular system, please try to answer to the best of your ability.

3. Regarding UBM and K-Span construction:

- a. What are the Pros & Cons of using the UBM?

- b. What are the unique challenges of using UBM?

4. Regarding Pre-Engineered Buildings:

- a. What are the Pros & Cons of using the PEBs?

- b. What are the unique challenges of using PEBs?

5. Regarding the FrameCAD system:

- a. What are the Pros & Cons of using the FrameCAD system?

- b. What are the unique challenges of using FrameCAD?

6. Is the USAF providing enough training for vertical contingency construction? Explain.

7. Are there other vertical contingency construction systems or methods that may be needed in the USAF? Please elaborate.

If you have any questions about this research request, please contact Dr. Brent Langhals (primary investigator) – Email: brent.langhals@afit.edu, or Maj William Bentley, william.bentley@afit.edu

Click to Save Responses

Upon Saving, Please attach this form and send to:
william.bentley@afit.edu and web007@gmail.com

Appendix C: Round 2 Email

AFIT Research: Evaluation of Contingency Construction Methods - Round 2 (Response Requested by 22 NOV 17)



Bentley, William E Maj USAF AETC AFIT/ENV

Thu 11/9/2017, 10:33 AM

Langhals, Brent T Civ USAF AETC AFIT/ENV; Gene Bentley <web007@gmail.com>; ↗

🔄 Reply all | ▼

You replied on 11/16/2017 9:33 AM.



Evaluation of Contingen...

37 KB

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🔒 The digital signature for <BENTLEY.WILLIAM.E.1270112575> on this message is valid and trusted. For more information, [click here](#).

BLUF: Due to your participation and responses on the first round, you have been identified as an Air Force Contingency Construction SME. Your response to the attached AFIT research questionnaire (Round 2) is requested by Wednesday, 22 November 2017.

Good Morning/Afternoon,

PURPOSE: You are receiving this email because you have been identified as a Subject Matter Expert in the field of Air Force Contingency Construction. I am a CE officer currently enrolled in the Graduate Engineering Management (GEM) program at the Air Force Institute of Technology (AFIT). The focus of this thesis effort is to evaluate the Air Force's current contingency construction methods.

BACKGROUND: Within the 2016 Civil Engineer Flight Plan, line of effort 2.4 states that the USAF needs to "create lighter, leaner, and more resilient contingency equipment and installations." For the purpose of this research, contingency construction is defined as military forces constructing vertical facilities (specifically PEBs, UBM K-Span's, or FrameCAD) at natural disasters, terrorist events, subversive responses, military operations, humanitarian operations, or remote operations. To develop this field of knowledge, the research team is performing a "Delphi Study" in which the research attempts to find consensus amongst SME's through several rounds of surveys. The second survey is attached.

SURVEY INFORMATION: Participation is completely voluntary and you may drop out at any time, with no adverse effects. The questionnaire is 10 questions long and you may write as much or as little as you wish. As you are able, please accomplish the attached survey by 22 November 2017. Further information about the study and questionnaire can be found in the attached survey. This PDF survey has a "Save As" button at the bottom of the form which should work to save your responses and then please email the response via an attachment back to me (william.bentley@afit.edu and web007@gmail.com) at your soonest convenience.

Please let me know if you believe that you have received this email in error. Additionally, if you have any questions or concerns, please let me know. Thank you very much for your time and consideration in this research effort.

V/R,

WILLIAM E. BENTLEY, MAJ, USAF
AFIT/ENV Master's Student
william.bentley@afit.edu and web007@gmail.com
Cell: (870) 904 4120

Appendix D: Round 2 Questionnaire

Air Force Institute of Technology Evaluating Contingency Construction Methods Research Questionnaire – Round 2

Purpose: The purpose of this study is to research and analyze the Air Force's contingency construction methods currently being used. For the purpose of this research, contingency construction is defined as military forces constructing vertical facilities (specifically Pre-Engineered Buildings (PEB), Ultimate Building Machine (UBM) K-Span's, or FrameCAD facilities) at natural disasters, terrorist events, subversive responses, military operations, humanitarian operations, or remote operations. The goal of this research is to evaluate and understand each of these construction methods. This research will be conducted via the Delphi Study method, in which the researcher contacts subject matter experts to help develop a consensus of opinion. The researchers will send out subsequent questionnaires to develop and refine expert opinions. At the conclusion of this research effort the researchers intend to publish and present the results, as well as brief those results to Civil Engineer leaders.

Researchers: Dr. Brent Langhals AFIT/ENV, and Maj William Bentley AFIT/ENV.

Disclaimer: As a survey respondent, you have the ability to self-eliminate from participating in any current or future surveys, at any time. No adverse action will be taken against anyone who chooses not to participate in current or future research. Survey responses will be recorded anonymously, and your comments will not be attributable to you when/if the research is published. Your responses will be maintained IAW the Privacy Act Statement of 1974. By filling out and responding to this questionnaire, you are hereby acknowledging and consenting to your participation in this research.

Privacy Act Statement: Your survey response contains FOR OFFICIAL USE ONLY (FOUO) information which must be protected under the Freedom of Information Act (5 U.S.C. 552) and/or the Privacy Act of 1974 (5 U.S.C. 552a). Unauthorized disclosure or misuse of this PERSONAL INFORMATION may result in disciplinary action, criminal and/or civil penalties. Further distribution is prohibited without the approval of the author of this survey unless the recipient has a need to know in the performance of official duties. If you have received this survey in error, please notify the sender and delete all copies of this survey.

Research Questions

This research defines contingency construction as military forces constructing vertical facilities (specifically Pre-Engineered Buildings (PEB), Ultimate Building Machine (UBM) K-Span's, or FrameCAD facilities) at natural disasters, terrorist events, subversive responses, military operations, humanitarian operations, or remote operations. Traditionally, contingency construction has been limited from initial bed down to 2 years, however, this thesis does not limit the contingency timeline and is considered from bed down to base closure, site closure, or mission completion.

1. Using the above definitions and based on your individual experiences and expertise, the top 3 USAF Contingency Construction Challenges reported were:

- 1) Materials (due to poor procurement timelines and/or quality)
- 2) Personnel (due to right amount and/or lack of expertise or training)
- 3) Equipment (due to the logistics/timing of moving it and/or having the right pieces available)

Do you agree with these challenges and are they in the right order?

If you could insert an additional challenge, what would it be?

The following questions should be based on your personal experiences and expertise, and are follow-up questions from the first round. If you have not worked with a particular system, please try to answer to the best of your ability.

2. Regarding UBM and K-Span Construction:

- a. The Top 4 Pros of using the UBM reported were:

- 1) Speed (based on how fast a UBM facility can be built)
- 2) Transportability (based on the maneuverability of the UBM)
- 3) Simplicity (based on the minimal engineering effort needed and/or designs)
- 4) Space (based on the ability to change dimensions or vary sizes per customer requirements).

Do you agree with these UBM Pros? Explain.

- b. The Top 3 Cons of using the UBM reported were:

- 1) Customization (based on a limited amount of designs)
- 2) Space (based on the ability to change dimensions or vary sizes per customer requirements)
- 3) Personnel (based on the amount of personnel needed to support the UBM construction effort).

Do you agree with these UBM Cons? Explain.

- c. The Top 4 unique Challenges of using the UBM reported were:
- 1) **Equipment** (due to equipment needed – ie crane and/or there only being one UBM available)
 - 2) **Materials** (due to various products available and their respective logistics and/or steel availability)
 - 3) **Personnel** (based on the amount of people needed to carry each steel arch and/or personnel trained on the UBM)
 - 4) **Training** (due to limited amount of training on the UBM)
- Do you agree with these UBM Challenges? Explain.

3. **Regarding Pre-Engineered Buildings:**

- a. The Top 2 Pros of using the PEB method reported were:
- 1) **Customizable** (based on the ability to customize floor plan and designs for each project)
 - 2) **Permanent** (based on the life span of PEBs)
- Do you agree with these PEB Pros? Explain.

- b. The Top 4 Cons of using the PEB method reported were:
- 1) **Logistics** (based on the long procurement timelines/process and/or delivery)
 - 2) **Cost** (due to the cost of using a contractor for designs/procurement of the building)
 - 3) **Equipment** (based on the specific equipment needed for construction)
 - 4) **Foundation** (based on the foundation/columns needing to be accurate/precise and/or the time this takes)
- Do you agree with these PEB Cons? Explain.

- c. The Top 2 Challenges of using PEBs reported were:
- 1) **Logistics** (based on the time required for design, manufacturing, and delivery of the PEB)
 - 2) **Foundation** (based on placing the foundation footers/columns correctly and/or the time this takes)
- Do you agree with these PEB Challenges? Explain.

4. Regarding the FrameCAD system:

a. The Top 3 Pros of using FrameCAD reported were:

- 1) Adaptability (based on the ability to be tailored to user requirements and/or anything can be designed)
- 2) Simplicity (based on the ease of use between the software and hardware and/or the actual construction)
- 3) Speed (due to how fast the machine can produce an entire building)

Do you agree with these FrameCAD Pros? Explain.

b. The Top 3 Cons of using FrameCAD reported were:

- 1) Cost (due to the initial costs, re-occurring costs, replacement parts cost, and/or licensing)
- 2) Software (based on the software not working well with other software and/or annual renewals)
- 3) Training (due to minimal personnel being trained on the FrameCAD system)

Do you agree with these FrameCAD Cons? Explain.

c. The Top 2 Challenges of using FrameCAD reported were:

- 1) Maintenance (meaning that the machine needs regular maintenance and/or repair kits)
- 2) New (due to the FrameCAD system not being an official UTC and/or it being a new technology to the USAF)

Do you agree with these FrameCAD Challenges? Explain.

If you have any questions about this research request, please contact Dr. Brent Langhals (primary investigator) – Email: brent.langhals@afit.edu, or Maj William Bentley, william.bentley@afit.edu

Click To Save Responses

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william.bentley@afit.edu and web007@gmail.com

Appendix E: Round 1 Responses

E.1 Best Contingency Construction Method and Challenges of Contingency Construction Responses

Participant	Best Contingency Construction	Challenge 1	Challenge 2	Challenge 3
1	It depends on the function of the building and the available lead times for the mission.	Not having the organizational agility to adapt/adopt emerging technologies is eroding our competitiveness to provide a quality and timely product to the warfighter when compared with contingency construction performed by contractors.	An increased reliance on contractors could leave the warfighter without an experienced, in-house execution method for those missions where contractor execution is incompatible with construction objectives (i.e. speed, austere locations, sensitive missions).	
2	If you are looking for an expedition facility to be built your UBM K-Span will be the best contingency method to use because the facility (overhead storage) can be built in a matter of weeks if you have the right material on hand before construction begins.	Material acquisition - This is the main challenge when it comes to construction, if you don't have the right parts or the parts period the building will not go up.	Weather - Self explanatory, you need the weather to be ideal conditions to do any type of construction.	Personnel/Experience - With anything we do you need to right amount of people as well as personnel with the knowledge and experience in doing the job your doing.
3	K-Spans given robust training, proven ability to adjust to sites, ability to reduce/limit major logistical hurdles given simplicity of structure, solid return on investment given nominal construction timespan, interior floor space, customization, etc.	Adequately planning for work beyond primary structure, i.e. finishes, mechanical, electrical etc extend projects to long	Insufficient design training leading to inability to adapt designs to sites, driving re-design	Inability to manage actual construction, no actual schedules or adherence to them.
4	K-Spans because they are quick/expedient, cheap, and easy to construct. I say this because nowadays base closure could be years down the line instead of a quick operation. However, for events like natural disasters, I think soft skin structures would be a better option construction-wise since they are even quicker to construct and short-term.	Materials: Many times material does not arrive on time or correctly and the procurement process has a lot of red tape and areas for bottlenecks (contracting).	Equipment: It takes a long time to get equipment/UTCs overseas.	Technical expertise: The Air Force does not stress a lot of technical expertise and you kind of need it in austere locations when you might not have a lot of reach back... especially for something like FrameCAD. Sidering amongst other units: A lot of different organizations want a piece of the pie which causes a lot of in-fighting within the Air Force (RED HORSE vs. Prime BEEF vs. CRG) on who gets to do what.
5	In my experience the Ultimate Building Machine may be the best piece of equipment for contingency construction. It is smaller and more maneuverable than a Frame CAD machine. It sets up much faster and easier than the amount of work that goes into leveling and preparing a site for a Frame CAD machine.	In a deployed environment it can be very challenging getting materials needed for construction, especially quality materials.	Likewise, the same can be said about construction equipment. Both can be extremely challenging to acquire in a remote location. This may be where the Frame CAD machine beats out the UBM in that you don't need as much heavy equipment to construct a Frame CAD building (once the foundation is poured) as required to construct a UBM.	Additionally, training can become an issue if members have PCS'd in and out of the unit and don't have any experience with a UBM or Frame CAD.
6	PEBs are our best form of vertical construction, due to the building life span and quick erection time. Also the numerous variations of length, size and height allow endless possibilities.	Materials- It can be a hassle to get all the materials you need for you project.	Tools- Having all the tools available to get your project done.	Experience- People not having gained the knowledge to do heavy construction.
7	After having extensive experience with all the above systems, I believe that FrameCAD or a similar steel form machine would be best suited for our contingency construction ops. The amount of time, manning and even waste that is saved by utilizing this technology would fit perfectly into our operations globally. Over my last few deployments our manning has dropped but our missions have stayed the same or even increased causing challenges on how we conduct construction operations to meet CDR's requirements. Having used the FrameCAD to support combat medics out of Fort Bragg, I can easily confirm that we were able to construct two large training facilities with much less personnel in a much shorter span of time. Additionally, K-Spans are fast but do to the appearance many have turned away from them over the years.	Training - We train consistently on our various methods, however with the mix of active duty, reserve and guard components used to support various contingency operations across the globe I believe we become complacent with thoroughly training and retaining well trained operators and maintainers for these systems.	Technology - I also believe that many of the methods we use are much outdated. I have had the pleasure to work with contractors that utilize ICF(insulated concrete forms), FrameCAD, NTM roof/siding machine and a variety of other means that would drastically improve our "do more with less" mindset.	Purchasing - We spend a lot of money to upkeep and maintain old systems. K-Span insulation is an example that I have had a chance to change during my time in the Air Force. Once using an old spray on methods required much maintenance, waste and extensive cost, as well as having to re-accomplish tasks after the product began to deteriorate. Now we use a better method with rolled insulation and pin welding. This would be much like utilizing the FrameCAD system over other methods. Paired with a roof panel machine much like the NTM would again save us time, resources and fit our current needs to support a wide variety of contingency operations.
8	Depends on the requirement and timeframe. For unexpected missions, K-Span is faster and easier for air transport. If there is adequate time to design, order and stage a PEB, the resulting facility is normally more reliable and versatile. Having a bunch of PEB shells on base gives mission commanders options in the future. K-Spans are more difficult to finish out interiors and modify uses as missions change. I believe Frame CAD was supposed to combine the functionality of PEBs with the portability and speed of K-Spans. I believe that of any employment exp	Requirement definition: In a dynamic environment, we are often chasing our tail trying to execute a construction program a year or two behind the identification of a need. This is partly due to poor planning at the contingency locations as well as variability in missions that we can't control.	Material acquisition: The AFs supply chain management is terrible. We are our own worst enemy in trying to execute work in a timely fashion. The contracting and financial bureaucracies limit the scope of our technical solution space and stifles innovation in the field. 90% of the projects that "failed" or had "issues" were due to a lack of money and materials in the right place at the right time, not because the engineers and craftsmen failed to execute.	A hollow force (in terms of skills and training): The 10% of projects that did experience issues due to inability of craftsmen or engineers was due to lack of training or experience. Prime BEEF is focused on PM and base maintenance at home station and then supposed to flip the switch to larger scale renovations and construction downrange with 1 Contingency Construction Project per year to garner those skills. For the past 3-4 years, we have been relying on experience from our NCOs/SNCOs and a few young engineers who grew up in the GWOT era with no experience. The younger generation of engineers are ill-prepared to execute construction mission based only on 1 home station with a ton of variability in the scope of training that project provides to each AFSC.

9	The UBM K-Span will be the best contingency method to use because the facility (overhead storage) can be built in a matter of weeks if you have the right material on hand before construction begins.	Material acquisition - This is the main challenge when it comes to construction, if you don't have the right parts or the parts period the building will not go up.	Weather - Self explanatory, you need the weather to be idle conditions to do any type of construction.	Personnel/Experience - With any thing we do you need to right amount of people as well as personnel with the knowledge and experience in doing the job your doing.
10	K-Span are one of the best contingency application the Air Force has. The versatility in building length makes it easy to manufacture a building of any size. It also has minimal earth work making the process one of the quickest. Furthermore, ordering building in a box from MIC Industries ensures all components of the project are on hand.	Personnel; not have enough man power to support any heavy vertical operations.	EA not being properly trained on auto levels, total stations and AutoCad.	Parts; acquiring the correct parts or getting material in a timely manner
11	There is no best method. The engineer has to determine what is feasible given the mission need, timeline, equipment/contracting/logistic support, and funding available. The flexibility to bring multiple solutions to the warfighter is the engineers duty.	Logistics/contracting support: Contracting process and material delivery is the biggest hinderance to project time lines	Equipment: Cranes, telehandlers, KSPAN machines (what is available can determine what can be built)	Manpower availability and skillsets
12	It's entirely situational dependent in my opinion. There is no silver bullet when it comes to vertical construction. Depending on the situation and requirement, I would likely recommend a different method. That said, I would struggle to recommend a k-span.	Lack of enterprise oversight and ownership: who owns the decision making?	Lack of standardization: every RH squadron builds a k-span a different way, so it makes rotational projects incredibly challenging	Lack of training/mentorship: not every RH squadron is training to same levels
13	For true, contingency environments K-Spans are the best option. Low cost, long life, and speed of design/production. RED HORSE can produce a K-Span from idea to completion in two months, with a very simple design and material that can be kept on-hand. The other methods take much longer and require large material purchases that cannot be made ahead of time.	Lack of direction in RED HORSE/Prime BEEF troop construction core capabilities: In AfcenT, 557 ERHS and the 577 EPBS are building MILCONS that are not contingency at all (i.e. large, complex DFACs in U.A.E. We have lost site of our core capabilities: simple K-Spans and PEBs.	Material procurement: takes forever in the AOR and leads to mission delays.	Bases in the AOR becoming permanent vs. contingency.
14	Although each technique has certain situations where it is "the best" or most effective method, FrameCAD facilities have the ability to have the longest lifespan. This is beneficial in recent contingency environments that have required an "enduring" presence with nation building and advisory missions. This system can be utilized stand alone or in conjunction with the other systems. Additionally, the FrameCAD system can be forward deployed to support a major bed-down operation or staged in a central location with materials shipped as required.	Availability of Materials. Certain construction materials require long lead times (such as PEB's) due to contracting requirements or design time that limit their availability for contingency construction.	Quality of Materials. Additionally, in typical contingency construction environments materials that are readily available are often of inferior quality than is required for safe construction.	Personnel Availability. Finally, during initial beddown operations, there is a greater demand on crafts requiring specialty knowledge.

E.2 UBM Questions Responses

Participant	UBM Pros	UBM Cons	UBM Challenges
1	bench-stocked materials, large free-spans, simplicity	wasted space at wall, aesthetics, \$ to MIC	Many times RH ends up constructing a building within a building (i.e. an interior buildout using the K-Span as a roof).
2	The pros when it comes to using the UBM is that it is easy to set up and operate. It can be transported easily to any deployed location.	The cons to using the UBM is having enough personnel to help with the carrying of panels when the metal comes off the machine.	Unique challenges using the UBM is picking the right location to set up the machine because depending on the size of the facility you will need to establish a huge foot print for producing the arches for the building. Also you will need crane support when lifting the UBM arches.
3	standardized designs easing design burden, ability to customize open space, spectrum of sizes, relatively simple physical construction	no ability to TRULY customize, limits given weather, wind, cannot make use of ALL interior space, necessities for cranes, specialized equipment	Must be trained on UBM; must have software and understanding of design parameters; effectively limited to single floor plan can be longer/shorter and can adjust width some but is always going to be a rectangle; various insulation products and lengthy timelines
4	Quick construction, very cookie-cutter, cheap compared to other vertical options (fits well for contingency construction...not pretty, but effective).	Dimensions are essentially the same, just bigger or smaller, so it may not meet specific requirements for facilities. Can't tailor the facility as well as other vertical options.	Need to ensure personnel are properly trained to operate machine. Usually there is only one UBM on-site so if that goes down and materials are hard to come by then you're screwed.
5	It is easily moved and set in place to begin use and construction. Once the UBM is in place and ready to run, a crew can set up all the steel pics for an entire K-span in a single day.	However, you are restricted to a simple K-Span design which may not be ideal in every situation. Additionally, UBMs typically won't operate correctly below freezing temperatures. If they have any frost on them they'll struggle to create proper steel arches.	To install the steel arches from a UBM the crew requires a crane which may not always be easily acquired. Also, a UBM requires a relatively large crew compared to FrameCAD construction. For K-Span assembly, you would need a crew of 5 running the UBM machine. You would require a crew of 5 to carry each steel arch from the machine to be seamed with other steel arches. You would need a crane crew, and you would need a crew of 5 or more seaming the steel arch pics together as the building goes up. Again, a UBM does not operate well in freezing temperatures.
6	Its a expedient way for vertical construction. You can have a building up within a month. Once you got you width and height site, you can run buildings out as long as you need them.	Typically a K-span is only a 20 year building life. It takes a lot of personnel to put the shell up, and if you don't have enough people on hand they are going to be exhausted after a day work.	The challenges of using the UBM in a deployment is the maintenance of the machine. Not knowing how long it has been sitting or knowing the last time somebody performed general maintenance on it. Getting the correct gauge steel from vendors, and the amount of shipping time it takes to get to a location. Part replacement if the machine breaks, you don't have the parts to replace it, the amount of time to would take to get a replacement part. You might not have a qualified operator to run the machine, which would time to your project, and take more steel to complete the project.
7	Fast operations, great support from MIC Industries, flexibility to vary lengths of facilities to meet customers needs.	Still requires a fairly large team, not as easy to repair or replace damaged parts in deployed environments. Aesthetically not as appealing to many customers.	One big challenge I have seen with the UBM is having fully capable and well trained operators and maintainers for the equipment. This can cause an excessive waste of steel during calibration which obviously causes lost time on a project.
8	Familiarity (in the case of RH), portability, speed	Limited use of completed facilities. Great for storage/industrial space, but less effective when people try to use K-Span as a one size fits all solution and then build out the interior for admin space, billeting etc..	Skilled operators: Using the equipment effectively takes knowledge and experience. There are always on-site challenges with K-Span that you need experienced members of the crew to overcome. Not something you can take a class on and be proficient. We always struggled with insulation. Recently there have been some updates in the insulation systems being employed, but as of 2013, the cellulose blown on insulation was a limiting factor in how long users were able to get use out of the facility.
9	The pros when it comes to using the UBM is that it is easy to set up and operate. It can be transported easily to any deployed location.	The cons to using the UBM is having enough personnel to help with the carrying of panels when the metal comes off the machine and having the space to position the machine and the run off panels.	The footprint you need to operate the machine and crane support o lift the arches in place

10	Fast, simple design, minimal foundation prep, mobility, and minimal material list	Amount of personnel needed for this application, crane operations, material waste, relying on one piece of equipment to fabricate the building and too many moving parts in the assembly process allows for defective arches	Relying on one piece of equipment to fabricate the building, too many moving parts in the assembly process allows for defective arches, improper check stations, defective panels, running out of coiled steel material, need to have a trained person to run the UBM
11	Rapidly deployable, easy to keep materials stocked, fast building construction times.	Limited flexibility in larger sizes (clear height in center) and building configurations	UBM does not create a large enough building to meet customers demand. 70' span is the largest building generally constructed. That means a PEB or a fabric structure has to be ordered. Mict Industries now has a larger machine the Mega Building Machine (MBM), which once perfected might meet Air Force needs better.
12		1. The steel is next to impossible to acquire in a timely fashion, particularly in the AOR. 2. Engineers do not fully understand the engineering behind k-span construction, so they rely solely on the results of the design software, which has its issues. 3. Limited applications and flexibility	Acquiring k-span steel will continue to be the biggest challenge for UBM construction. For the typical procurement timelines, I can typically acquire a PEB and construct it on a similar timeline. PEBs have greater flexibility.
13	Limited requirements for material (can be kept on-hand). Flexible in size. Quick to construct and low cost.	Wasted space due to curved walls Size limited due to UBM 120/240 capabilities. Limited lifespan (~20 years)	Convincing customers to accept a K-Span as meeting their needs can be a challenge. K-Span steel roll specifications are strict and can be difficult to obtain in the AOR.
14	Simplicity- Minimal design experience required; Large clear spans- can be built out or left open; Raw materials can be stock piled and stored; easily transported; proven design; CE community familiarity	Crane required for construction; complicated concrete/foundation construction (multiple small pours required); significant loss of space if interior build-out required; specialty insulation; short design life-span; minimal civilian market	The UBM system's simplicity is both its greatest weakness and strength. The UBM is perfect for constructing large, open structures quickly. If the finished structure requires additional interior build out or finish work, the building shape becomes cumbersome and limiting.

E.3 PEB Questions Responses

Participant	PEB Pros	PEB Cons	PEB Challenges
	1 more permanent, aesthetics, efficient space usage, no technology owner (MIC, FrameCAD), crossover experience available from civilian sector to leverage ARC 2 Pros to using a PEB is that the building comes prepackaged and labeled, so it should bolt together without any complications. 3 ability to customize floor plan/height, better use of available space, more options with interior, stories, mech/elec systems 4 Can be tailored to withstand any environment or user need (not a basic cookie-cutter structure), structure goes up fast once foundation complete.	long lead times Cons to using a PEB is getting the foundation footers correctly so that you do not have any issues when installing the vertical posts. Insulation techniques are not as standardized, longer lead times on materials/steel, complexity of construction, higher level of finish often leads to delays Foundation requires more accuracy and alignment of column footers, structural steel and panels are a very long procurement process, takes a little longer to build, usually more expensive	RH doesn't typically have bench-stocked PEBs. The long lead time creates timeliness issues for material procurement for rapidly changing mission timelines. PEB's unique challenges are making sure that the foundation footers are placed correctly and square so when you are placing the vertical posts you do not have any issues when it comes to tying in the beams for the PEB. The higher level of customization of facilities, basically each is a one-off leads to facility unique material and design issues that have to be resolved in the field and not all teams are prepared to do so. As facility is a one-off steel members are then project specific and there is a long lead time there, leading to an agility/responsiveness issue. Footer design and alignment. Material procurement.
5 I have never worked with a Pre-Engineered Building	6 Once the project is complete you have a 50 year life on PEB.	I have never worked with a Pre-Engineered Building	I have never worked with a Pre-Engineered Building
	7 Very universal in what the PEB can be used for. Adaptable design and a solid facility.	If you don't have the crane support or genie lifts to erect your steel you won't be able to go vertical until you have that equipment available to use.	The biggest hassle of PEB's is getting your footer correct, and making sure you have the equipment you need to start construction.
	8 Versatility, functionality, aesthetics	Much more extensive designing and planning. Requires a larger team. Largest downfall is the time required and the establishment of the columns utilizing the j-bolts.	Many different manufacturers causing several differences in construction from one facility to the next. Again, column placement and j-bolt patterns are the most time consuming, however, this is also a more outdated way of securing this style facility as many contractors use faster anchoring systems.
	9 Pros to using a PEB is that the building comes prepackaged and labeled, so it should bolt together without any complications.	material lead time and delivery, material handling and equipment required to erect	PEBs are hard to get into theater on our usual last minute timelines. They take longer to construct and require a skillset to erect safely that we rarely ever practice at home station outside of a handful of RED HORSE TTPs. End product is great, but getting there comes with logistical challenges.
	10 Simple assemble, minimal crew, minimal crane usage	Cons to using a PEB is getting the foundation footers correctly so that you do not have any issues when installing the vertical posts.	PEB's unique challenges are making sure that the foundation footers are placed correctly and square so when you are placing the vertical posts you do not have any issues when it comes to tying in the beams for the PEB.
	11 Engineering work performed mostly by others. You order the building for what the project requires. Easy to assemble. Highly skilled craftsman are not required.	mislabelled components, longer foundation prep and material size, mobility and weight	Need a competent crane operator and more specialized material components
	12 PEBs provide greater flexibility and functionality for the customer and the engineers doing the work. Additionally, you have access to a larger network of suppliers and ability to hire SMEs for construction.	Long lead time (3-6 months normal), assembly time in the field.	PEB's are straight forward. Time lines for both procuring and construction are the biggest challenges. The other big issue is a PEB is construction.
	13 Long life. Meets some architectural/aesthetic standards and expectations. Can be built to any size or shape.	Cost and production timeline. The PEB you order is the PEB that you will build.	Most RH engineers do not know that PEB suppliers will not supply a foundation design, leaving them to either have to contract it out or do it in-house. In-house design is relatively easy, but I don't think the training is universal to reliably do it. RH needs some civilian engineers. Furthermore, the foundations are more complex than on k-spans.
	14 Long design lifespan; multiple stories; fully customizable; efficient use of space; large clear-spans; multiple roll-up doors; flexible space if mission requirements change	Expensive and take longer than K-Spans. Requires a few months of contracting, design and fabrication for a PEB firm to build the PEB steel and plans.	In the AOR and in the CONUS, many mission users request CMU (concrete block) stem walls to be placed along the sides of all occupied building for the sake of AT/FP. This really eliminates the advantage of a pre-designed building with pre-constructed wall/roof panels.
		6+ month lead time; significant foundation design experience required; Surveying of Column & foundation required; Crane required for construction	The largest challenge for PEBs is in the lead time required for design and manufacture. This can make it difficult to meet beddown timelines. PEBs lend themselves best to single structure projects in enduring environments.

E.4 FrameCAD Questions Responses

Participant	FrameCAD Pros	FrameCAD Cons	FrameCAD Challenges
1	bench-stocked materials, ease of construction, adaptable	start-up cost, increased training on taxed craftsmen	It's a technology that's not readily-accepted and the equipment is not currently on RED HORSE UTCs.
2	Pros to the FrameCAD machine is that it's a very easy system to use if the software/design is developed correctly.	Cons to using the FrameCAD is the software needs to be updated yearly, someone needs to know how to use FrameCAD detailer/structure software. Because with having someone knowledgeable using detailer or structure you have a machine that can't be used.	Challenges to the FrameCAD is the software needs to be updated yearly, someone needs to know how to use FrameCAD detailer/structure software. Because with having someone knowledgeable using detailer or structure you have a machine that can't be used.
3	Insufficient experience to have an informed opinion.	Insufficient experience to have an informed opinion.	Insufficient experience to have an informed opinion.
4	Fast production of steel members, can be tailored to meet user requirements, transportable	Most people have never heard of it or are trained on it, very small market for replacement parts or building materials, not readily available	No one knows about it...
5	A FrameCAD system offers the opportunity to design and build a more complex facility. Anything that can be designed within the scope of the FrameCAD software can be printed and constructed from the machine. Once printing of steel frame begins, the building walls can be constructed in a matter of hours. It is remarkably fast to put the printed walls together.	Unfortunately, the FrameCAD machine is a more complex piece of equipment and can (and does) breakdown. This can leave an average construction crew without the means to easily repair it.	The FrameCAD machine uses an extensive hydraulic system which is susceptible to failure. This can create long delays if problems arise. Additionally, the unit has to be placed on solid level ground. This may require a great deal of time being spent preparing an area just for the FrameCAD machine to sit and operate. Once this is accomplished, it is not easily moved to another location.
6	Being able to produce a building from a machine in days, how it punches all the holes for the screws and simple the erection is.	The availability of replacement parts can be a challenge, if something on the FrameCad machine breaks, it has the potential to shut down your project until replacement parts come in.	The challenges of using the FrameCad machine are you need to have a operator who is versed in running the machine and able to do the maintenance on it. If a small part breaks on it and you don't have a replacement it could potentially shut down your construction site.

7	Pros - Ability to drastically do more with less. Realistically, the machine requires two machine operators and one equipment operator (for steel loading procedures), an assembly crew (4-8 personnel depending on scope and speed). - Rapid replacement of damaged or faulty framing components. Each stud or stick member is labeled and can be replaced and reprinted by a few simple steps alleviating downtime. - Easy checks and calibrations to ensure all specs are kept throughout the project. - Easy maintenance and disassembly in the event of any jamming of steel through the rollers. - Minimal waste, most the waste comes from calibration which on the flip side anything over 4-6' is used for bracing. - The flexible ability to produce just about any building type needed to meet our mission. Can be used for dorms, double stacks, TOCs, maintenance facilities and storage which would reduce the time and manpower during construction.	Cons - Software licensing agreements where roughly \$8-10K and require purchase every year. - Software does not talk to AutoCAD. Meaning, once it is designed in FrameCAD the EAs have to redesign it in AutoCAD as the two were not compatible. Not sure if FrameCAD has corrected or patched this since. - Primarily a metric system but is available with an imperial standard upgrade. With the metric system, we found ourselves converting and adjusting walls and stud spacing frequently.	During my use of the machine I have not found any unique challenges. We did learn to build an extensive repair kit, as a blown gasket could shut down operations. Repairs are easy to make so long as we have a well built kit.
8	versatile facilities while maintaining portability, can be tailored to meet user needs	Entirely new building system that personnel need to be trained on	Lack of experience
9	Pros to the FrameCAD machine is that it's a very easy system to use if the software/design is developed correctly.	Cons to using the FrameCAD is the software needs to be updated yearly, someone needs to know how to use FrameCAD detailer/structure software. Because with having someone knowledgeable using detailer or structure you have a machine that can't be used.	Challenges to the FrameCAD is the software needs to be updated yearly, someone needs to know how to use FrameCAD detailer/structure software. Because with having someone knowledgeable using detailer or structure you have a machine that can't be used.
10	simple assemble, minimal crew and mobility	software, certified operator, application usage, metric system application, running out of coiled steel material, relying on one piece of equipment to fabricate the building	Assembly components are specialized, metric system design and too new of a process, not every has the capability to train with this special cape
11	No Experience with FrameCAD	No Experience with FrameCAD	No Experience with FrameCAD
12	FrameCAD has the potential to be a real boost to AF contingency construction provided it is appropriately resourced, trained, and implemented. The fact that it is scalable and able to adapt to various customer requirements offers a big improvement, provided steel is available. Additionally, the design software is compatible with our existing systems.		No one really owns RH at an authoritative level enough to champion the program or provide decision making support. As a result, I'm not sure how FrameCAD gets implemented enterprise-wide without each squadron doing it on their own, but that won't get training or a UTC created for it. Without a UTC, how would you deploy this skillset?

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| 13 | Very quick construction system. Replaces wood and steel studs which can be difficult to obtain in the AOR. Completely customizable. | Limited to two story height. Width of spans limited. | Not yet accepted as a USAF contingency construction capability. Software and machine are very specialized and expensive. |
| 14 | Simple and familiar construction; scalable to meet mission requirements; can supplement other techniques; rapid construction; easily transported; scalable construction (from small single story to large multi-story); can employ "non-construction" skilled labor to assist; can use "off-the-shelf" designs; no crane required for small construction; can be used for large scale bed down or "one-off" projects; similar to civilian techniques (industry to learn from) | significant design requirements to create initial designs; specialized software; additional training required to maintain the machine; requires companion siding machine | Since the FrameCAD system is a new capability, a significant effort will be required to develop "off-the-shelf" designs and training operators and qualified designers. |

E.5 Training and Other Construction Methods Responses

Participant	Training Question	Other Methods
1	The best training is actual construction. In that regard, active-duty is much better off than the ARC component. In the ARC, the primary training opportunity each year is a Deployment-for-Training (DFT). There are very few DFTs that incorporate K-Spans, PEBs or FrameCAD. DFTs are primarily CMU or renovations.	Possibly, but they need to replace an existing technology and not just put more on the craftsmen's plate.
2	Yes we have enough training for vertical contingency construction that we now use in the USAF.	The USAF needs to get with outside agencies on what methods (i.e. tilt-up building construction) they are using because we are not setting are personnel up for the outside world when it comes to vertical construction.
3	Having been RMS, and an ECES/CD. No. There is an expectation that Airmen will make it happen, and they do, but after a learning curve, which means they were not prepared the day they hit boots on ground. Structural steel, reinforced concrete is not something even the most skilled Airmen is effective at off the street.	As mentioned in my experiences, CMU, cast-in-place, and pre-cast construction also have their place. Each has their own niche, but when working in a BP/BC environment they ar
4	No. All the vertical construction happening right now in the AOR are PEBs, LAMS, and some K-Spans...most CE troops (which make up the vast majority of the force) have never dealt with this kind of construction yet many times they have to augment RH since RH does not have enough manpower to meet all the requirements.	LAMS/tension fabric structures if the base/location is meant to be temporary like for hurricane relief.
5	RED HORSE is doing a tremendous job of training and preparing its Airmen for vertical construction requirements down range. However, it isn't until Airmen get to RED HORSE that they get that kind of training. Most CE Airmen would not be able to accomplish the task of constructing a K-span without a great deal of training and oversight from more experienced technicians that have been in RED HORSE.	None that I know of.
6	I think the opportunities are there to get the training and experience home station, but it up to the units to make sure there people are trained and getting ready for the contingency environment back home.	No, I think we are already stretching ourselves to thin with the UBM's, PEBs, and FrameCad construction, and having SME and operators that we don't need to add anymore constructions systems to it.
7	My honest opinion is no. Many times funding is an issue with sending people to some type of formal training. Additionally, the old ways of doing things have become a barrier in allowing our Airmen a chance to seek out better ways to perform contingency construction. I also do not believe we have a strong channel to enhance our construction methods. Sending Airmen to advance training courses in Gulfport, MS is not going to improve our knowledge of construction for military operations.	ICF (insulated Concrete Forms), we utilized these at USAFA and have had numerous other facilities where ICF would have been a much better option. Many facilities at enduring deployed locations require hardened facilities for advanced protection from potential IDF. CMU had been a "go to" for many. ICFs would allow for flexible designs, rigid construction with a monolithic pour. Having first hand knowledge and seeing some of our adaptive construction methods, ICF would also be a better construction method that would provide another advanced capability to our military engineers to
8	No. See #3 in challenges. We are relying on a CCP, which is normally a small enhancement job that happens once a year and maybe silver flag training to keep our Prime BEEF forces ready to go downrange and execute the ECEG mission which includes much larger scale construction. This is OK for the experienced craftsmen who have seen it all as part of OIF and OEF, but without a more rigorous training program or emphasis on additional CCPs in lieu of some of the base ops and mx work at home station, the younger Airmen will be ill prepared to take on these types of missions and lead them in the future.	Low tech solutions are a skill we overlook. Depending on the contingency, using locally available materials and methods might be the most effective way to move from initial BEAR asset to sustainment. This could include CMU, cast in place concrete etc.. We don't always have to build to US standards to meet the requirement.
9	No, I feel that we could always need more training due to the amount of people that come and go in the military.	The USAF needs to get with outside agencies on what methods (i.e. tilt-up building construction) they are using because we are not setting are personnel up for the outside world when it comes to vertical construction.
10	No, training is focused on maintain instead of building.	No, keep it simple. We work in a career field where continuity is important. Making processes easy ensures the ability to construct in any type of contingency environment
11	No. Our structural craftsman are expected to known building/maintenance techniques that are done by 8+ different career fields on the outside.	Yes, AFCEC/CXA is currently exploring Foldable/relocatable PEB's and other rapidly constructible facilities. If you would like to discuss more give me a call or email http://www.dogwoodindustries.com/ http://www.rapidbuilt.com/
12	On the craftsmen side, I think we need more consistent training conducted by experienced individuals that can provide continuity and reachback (i.e., civilians). On the engineering side, I think there is a significant void that needs to be addressed. I know of multiple examples where lack of engineering experience almost got people killed.	I think tensioned-fabric shelters should continue to be the standard for hangars and large, open-bay warehouses; therefore, I think future vertical construction methods should focus on solving how we build everything else (e.g., admin space, living quarters). Personally, metal building systems are my preferred method for troop construction.
13	If we are going to adopt FrameCAD in the USAF and specifically RED HORSE, then training needs to be funded and mandated. RED HORSE is well competent in K-Spans and PEBs. Prime BEEF should not be building these types of structures as they are a light construction entity with little to no training in construction.	We may need to look at/bring back SEA Huts/8 Huts. These simple designs used to be the AORs best method of replacing tents and was taught at AFIT in WENG481. These are very flexible lodging/office buildings, but it is no longer in our core competencies or training curriculum to be able to build these, should they be required.
14	The USAF is not providing enough training for vertical construction. The AF spends significant time training craftsmen and engineers on these systems, for them to only practice this training a handful of times. There is significant corporate knowledge that leaves when experienced craftsmen rotate to a new assignment. This is knowledge that can only be gained through experience. As a civilian engineer, it takes years of experience on projects to be considered an expert whereas with the AFs current model, engineers are expected to be experts after a training	

Appendix F: Round 2 Responses

F.1 Challenges of Contingency Construction Responses

#	Agree?	Add'l Challenges Comments	Add'l Challenge	AC2	AC3
1	Yes	I agree those are the top three challenges in roughly the right order (personnel and equipment should be equally weighted). I do not feel any additional challenges as should be weighted as heavily as the three listed above.			
2	Yes	I agree with the challenges and they are in the right order. An additional challenge would be weather conditions .	Weather		
3	Yes	An additional challenge, but it could fall under personnel and material, is the schedule creep that happens due to personnel not knowing what they need to order to to complete internal buildouts, and this delay significantly extending timelines. Really, I feel, these three challenges reinforce and intertwine themselves to become all the problems we have.	Schedule		
4	Yes	These are the top three concerns when doing contingency construction. Materials are definitely the top concern regardless of type of unit, but personnel and equipment can be interchangeable between # two and three. Other potential challenges may include host nation/base/third party coordination, transportation (air), and design limitations.	Host Nation Coordination	Transportation	Designs
6	Yes	I would say the 2 and 3 both the equal in priority , since they rely on each other to start/complete the project.			
7	Yes	I would agree that all three are our main challenges or issues throughout contingency construction. I do believe they fluctuate in order . Prime example is that I am currently on a back to back deployment to the same undisclosed location. The last team I was with here had about double the personnel but still holding about the same as our mission scope on this rotation. Additionally, there are still logistic issues with many of the materials required to include but not limited to PEB steel varying from the plans and inconsistent concrete not meeting requirement for strength. These are on going issues that are causing project delays from one rotation to the next.	Logistics		
8	Yes	Personal experience would put equipment ahead of personnel, but agree they are all challenges and materials is definitely #1. If I could add 1 more, it would be	Experience		
10	Yes	Planning phase, having 90% drawings	Planning		
12	Yes	I still believe that lack of enterprise management/decision-making is a central issue; however, I agree with the three issues mentioned here. I would argue that personnel should be ranked higher . A lack of standardized and robust training often causes issues with materials and equipment, as project planning is often not as detailed as it should be.	Management		
13	Yes	I agree completely. An additional challenge I might add would be contingency engineering design . Very few 32E officers have sufficient actual engineering experience to be confident in designing contingency structures. RED HORSE and some AFIT CE School classes provide a good background, but otherwise formal/informal training is non-existent until actually deploying.	Designs		
14	Yes	I agree with these challenges as well as the order. I would add that funding is an issue that has a significant impact on contingency construction.	Funding		

F.2 UBM Pros, Cons, Challenges Responses

Top Pros	Comments	Top Cons	Comments	Top Challenges	Comments
1	Yes		No	Yes	
	I think the biggest advantage of the K-Spans is the flexibility having the bench-rolled materials (coils of steel). I would include that in the Speed (or a Logistics) category.		I think it's a fairly resource-intensive effort for constructing a building within a building (i.e. an interior buildout using the K-Span as a roof) and I would put that in the Top 3 Cons. Plus, MIC has a monopoly which leaves us vulnerable.		
2	Yes	Yes		Yes	agree and still one more challenge should be added again that been space available.
	Totally agree with the pros for the UBM because it is a great tool to have when it comes to building a quick structure for either temporary or permanent solution.		Cons are spot on as well but the space is also limited because depending on the building size itself you need the additional space to print out the full panel and also curve the panel, then another area to seam the panels together.		
3	Yes	No		Yes	I would reverse the training and personnel challenges, given other projects requirements, the team size needed for a k-span, specifically steel work is less an issue than training on UBMs.
	I concur with these 4 pros, especially as they combine to mean that K-Spans are the most reliable construction we, USAF, can put up.		I disagree with personnel being a con, just be sheer numbers, as in my experience a K-span takes less personnel than a PEB. However, the skills to run a UBM do take trained folks and if you dont have a solid expert the project will stall.		
4	Yes	Yes		Yes	Yep, several single points of failure with equipment and material. The order seems correct. Equipment and material seemed to be major delays deployed.
	The top benefits are speed and simplicity (coolie cutter). I'm not too familiar with the transportation benefits. If it's easy to ship then cool, but I imagine if something breaks during transportation, it might be difficult to get it fixed depending on the location due to the UBM being a specialized piece of equipment. It's also cheap and can last long relative to the cost.		Need to make sure personnel are properly trained, particularly RED HORSE. And due to shape of K-Span, only so many floor plans and bldg purposes can be utilized.		
6	Yes	No		Yes	
			I wouldn't agree on the customization being a con because I think you can vary your designs with your height, width, and the fact that your length can be customized to the requester needs for a facility. Also if they room also it, if they need more space and didn't get the height they requested they could make up for by adding the length to the building.		
7	Yes	Yes		Yes	
	Here the speed, similar to the FrameCAD make K-Spans a much more expedient piece of equipment. A well trained and experienced team can have a building up and enclosed in a matter of days.		I also agree with the cons but would also add training as a con as well as a challenge due to the difference between the 240 and 120 K-Spans. From my experience the 240 requires nearly double the amount of personnel due to the greater size and much heavier operations than the 120. In addition, not as many Structural 3E3's have had formal or OIT type training which is reflected in a deployed or contingent environment. Finally, a common theme I have seen in recent years is that many customers or bases do not want K-Spans due to the appearance.		
8	Yes	No		Yes	I would add that in terms of materials, the steel and roll-up doors are the only items required that are difficult to get, and if there is a shortage of steel, that is a function of poor planning/leadership because it's easy to buy and keep on the shelf.
			Not sure how space is a con....agree more with having it up above as a pro. You can easily alter the width and build it as long or as short as you want. I think the con is that once constructed, it is difficult to retrofit or renovate. Trying to use K-Span as multi-purpose facilities by adding windows and doors in the sidewalls is a disaster.		
10	Yes	Yes		Yes	
12	Yes	No		No	
	I fully agree with transportability, but could only agree to a lesser extent on the other three. With the material issues, I'm not convinced that a k-span is faster to construct from concept to facility turnover. Additionally, the comment on minimal design is misleading, as I believe this pertains more to the concept of using standard designs, which would impact flexibility.		I'm not sure how 1&2 can be cons and be considered a pro simultaneously. Customization is a problem, since you're effectively limited based on the machine, software, and materials (i.e., you're constrained to certain shapes/geometries). I'm not sure that number of personnel required for a k-span is that vastly different than for a PEB.		I would agree on 2, 3, and 4 being unique challenges to k-span construction, but would disagree with 1. Customers in CONUS don't typically want k-spans, which makes training difficult and limits material suppliers.
13	Yes	Yes		Yes	I agree. Although, other than the rolled steel (which should be kept on-hand in large quantities), all materials are very easy to procure.
	I do agree; however one key pro for the UBM (in line with Simplicity) is that the basic materials can be immediately available. I.e. to build the basic structure of a k-span only steel, concrete, rebar, and dowels are required. These are not specific to the building and can be kept on hand, ready for the next emergency structure needed.		I agree; however the main reason K-Spans are not used in many cases comes down to Design/Aesthetics (similar to Customization/Space). The issue is that many bases (including in the AOR) will not accept a K-Span as it just doesn't match the shape/style of their typical PEB steel/CMU buildings. There is also a perceived shorter lifespan, although I haven't heard any evidence to suggest that K-Spans cannot last at least 20 years. Finally the shape (large arch) limits the ability for overhead doors on the sides and results in some wasted space along the walls where the arch reduces the available ceiling height.		
14	Yes			Yes	
	I agree with these pros. I would note that although K-span lengths can be increased easily, if wider spans are required, a larger UBM is required and due to the available shapes are limited. As far as simplicity, they do provide a very customizable finished space, however the construction order is non-typical and ultimately requires relatively small concrete orders spaced throughout the construction sequence. If reliable concrete is not available this could pose an issue. Additionally, in the simplicity category, I would note that although the UBM software provides "designs" for the foundations, it is a very rudimentary design based on minimal inputs. At the very least these designs should be reviewed by a competent engineer familiar with the specific soil conditions of the site and validated or modify as required. This is not a knock against the UBM software as it would be unreasonable to expect it to take into account all of the potential soil variables since it is a structural software.		The personnel requirement for the construction of K-Spans should be the top issue in my opinion. First, although the machine is not overly complex, it does require some specialized training and calibration. Secondly, the manpower required to safely transport the individual arches dictates that either skilled craftsmen must be pulled from another task or a source of un-skilled labor must be available. Finally, a crane and competent operator must be available to install the individual Picks. Considering the proximity of a large work force to the pick during install (including the seamers on the installed arches), K-span construction is not the right time to train a new crane operator.		

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F.3 PEB Pros, Cons, Challenges Responses

Top Pros	Comments	Top Cons	Comments	Top Challenges	Comments
Yes		Yes	I would not agree with equipment. Besides a crane, there really isn't specialized construction equipment required for PEBs. In fact, that's an advantage that there's no technology owner and PEBs are commonly done in the civilian sector.	Yes	I agree with #1 being far more important than #2.
1		Yes	Even with the four cons listed I believe the PEB is still the best choice right now for construction.	Yes	Those are only challenges if the planning process is not done on time and correct.
2	I agree the PEB is one of the better solutions when it comes to construction because of the pros listed.	Yes	Agree with 1-3, foundation is an example of training/personnel constraint. Structural concrete foundations is just not a skill Airmen can walk in and perform, and is more difficult to train on than URM, as foundations are doing to site specific.	Yes	Please see comment for question b., as rationale applies here as well.
3		Yes	PEBs do take longer during both planning and execution, but you get a longer term, higher quality product. However, this may not be needed for a typical contingency effort. I think that the military (particularly the Air Force) needs to redefine contingency—we are building too many permanent structures in the AOR.	Yes	The foundation should not be a problem if you have the right personnel...so I'd chalk that up to training as the actual challenge. Logistics (to include coordinating designs with the PEB manufacturer) and materials are still the number one challenge.
4	As part of the customizable benefit, it can be more structurally stable during seismic, wind, and/or snow events...at least it can be designed to have a higher structural capacity during such events.	Yes	don't agree with the cost being one of the cons, because it standard procedure when purchasing a PEB to having a contractor design/make the PEB. I think it is a positive to have the company send you the designs beforehand so you can verify and or dispute that certain things are right or wrong so they can be fixed before the PEB is manufactured to your needs. That is would help eliminated any changes on the fly after it been certified by the company.	Yes	Yes, with the logistics side I would also add the time it has been sitting on the ground from the delivery to construction time. Since the longer it has been sitting there, there is more potential for parts/screws/nuts and bolts to get lost, used on different building/project, or get misplaced or moved numerous times before construction is a big factor in the logistics.
6	However, the the pro of customizable still brings limitations with the PEB. If there is interior build-out this is an additional cost in materials, manning and resource separate from what a PEB offers. Meaning the PEB design does not include interior steel or framing members for walls, just or any other required structural members.	Yes	Agreed but again, crane support or manlifts are required for both PEBs and K-Spans. So in deployed or emergent requirements this becomes not only an issue for the equipment but also ensuring the manning requirement reflects a certified and preferably experienced crane operator and at least one rigger as well.	Yes	
7		Yes		Yes	
10		Yes	Agree with all four of these issues, but would suggest that the equipment for a PEB is not that much different than for other methods.	Yes	Agree with both issues. I would add that this survey focuses heavily on the craftsmen aspect of contingency construction, but our engineers also play a large role in PEB on the design side. PEBs are considered permanent construction (i.e., higher level of standard) and often require foundation designs, both of which are typically not taught to our engineers.
Yes	Agree with both and would add that PEBs are designed by licensed engineers, who design PEBs for a living. It reduces the risk of a structural issue considerably. PEBs also provide for multi-story and large clear span construction.	Yes		Yes	I agree; however I think the key challenge is managing missions, aesthetics, and customer expectations in the AOR. It seems that everyone in AFCEM wants a PEB, but sometimes a K-Span can do the job much quicker/cheaper. Also understanding of what RED HORSE/Prime BEEF contingency capabilities in the AOR is limited. Many of the large PEBs (i.e. permanent DRACs) exceed USAF Troop Labor primary capabilities.
12	I agree. Included steel and foundation engineering designs are a nice feature as is the ability to use pre-insulated panels.	Yes		Yes	The foundation challenge is significant, however often overlooked/ down-played. Proper design of this foundations requires experience and expertise that is not common knowledge CE wide. Knowledge of the site-specific soil conditions is required to properly size the foundations. Additionally, the design engineer must be capable of properly designing the foundations themselves from a structural stand point. Finally, the installation of the J-bolts requires an experienced and competent surveyor.
13	I agree, PEBs would be the ideal construction method for these reasons if the below Cons were able to be addressed.	Yes	I agree that the largest issue with the PEB is the logistics. All of the other issues can be addressed, however the logistical obstacles are outside of the Air Force's realm of control. The required time to design and manufacture the steel is set by the industry.	Yes	
14					

F.4 FrameCAD Pros, Cons, Challenges Responses

	<u>Tops Pros</u>	<u>Comments</u>	<u>Top Cons</u>	<u>Comments</u>	<u>Challenges</u>	<u>Comments</u>
	Yes	I agree but would also include the flexibility of having the bench-stocked materials (coils of steel). I would include that in the Speed (or a Logistics) category.	Yes		No	Not sure I completely agree with maintenance as one of the top challenges. I think I remember hearing anecdotally that the maintenance required for FrameCAD was much less than that required for UBM machines. Maybe it was just replacing some rollers but I'll defer to the author on that one.
1	Yes	Being a new construction method used in the Air Force the FrameCad is a great asset to have but it is not used to it's full potential.	Yes	The yearly software updates and not having the proper training on the machine/design software limits the potential of using the machine.	No	I agree with the maintenance challenge but not it being new. Just like any other machine it needs scheduled maintenance and replace parts but it doesn't break as easily as other machines would. The machine being new would not be a challenge because with the proper training it being new should not matter when it comes to the operation of the machine.
2	Yes		Yes		Yes	
3	Yes	Agree based on what I saw. However, this is all based on training that is currently very limited and specialized. Also, if it's just a metal stud building, you can only adapt it so much (i.e. I don't think you can build a big aircraft hangar with large bays using FrameCAD)	Yes	It's a very specialized system right now and not many people know about it. The lack of availability/training/material makes it a non-asset in the AOR.	Yes	Even more specialized than the UBM so if something breaks, it could be hard broken for a while. Also, know one knows about it.
4	Yes		Yes	I agree, but I would also add the transportation of moving the FrameCad machine and container great distances away is Con as well. It due to the fact transportation of the 40' long trailer it is kept in, would be a transportation nightmare unless it going to be kept in one central location.	Yes	Yes, but also add that part of these problems are also due to the fact that there is only one FrameCad location in the serving Europe and the Middle East to reach out for the training/helping with the maintenance.
6	Yes	Agreed. This is where the FrameCAD or similar systems Yes surpass the PEBs and K-Spans. Unlike the other two systems, FrameCAD is universal for both exterior and interior framing without the need of additional resource planning throughout both phases of construction. Speed on this one is also slightly dependent upon the exterior sheathing method as well.	Yes		No	Disagree with maintenance. Just like any piece of equipment ie. the UBM, welding machines, or anything else it requires maintenance to keep it running at optimal levels. However, I have received formal training on the maintenance of both UBMs and FrameCAD and find the FrameCAD easier to troubleshoot and repair.
7	Yes		Yes		Yes	
8	Yes		Yes		Yes	
10	Yes	Additionally, FrameCAD is a worldwide company and is in use in private industry, which provides a level of support that UBM construction cannot. Additionally, FrameCAD offers the ability to execute multi-story construction.	Yes	Agree, but would offer up that FrameCAD is one company that sells this particular capability. Some of these cons could be addressed or mitigated by another manufacturer. #3 is a result of not having FrameCAD officially adopted and assigned to a UTC.	Yes	These issues go hand-and-hand together. RH procured this capability without making it a UTC, which has caused a lot of issues related to deployability, maintenance, training, and enterprise adoption. #2 would need to be fixed before any other issue related to FrameCAD could be addressed or advanced.
12	Yes	I agree. Also the ability to use rolled steel for studs (easily shippable) vs. lumber which is cumbersome and not readily available in the AOR.	Yes	I agree. We need the time to train and use the system.	Yes	I agree. #1 challenge is the need to deploy at least 2 FrameCAD systems to the AOR, plus backup parts and software, in order to reach IOC for this method. Until that is done, FrameCAD will only be experimental for the USAF.
13	Yes		Yes	I would put the software concern at the bottom of the list because FrameCAD has been pushing out updated software that is "supposed" to be more compatible with other programs. Also, they have expressed interest in providing multi-year licensing agreements that could be negotiated at an AF wide level if the system gains enough support and momentum.	Yes	I don't think that the FrameCAD system requires unreasonably more maintenance than the UBM system. It certainly has more moving parts than the other systems, however since the machine is mostly self contained, it operates in a more controlled environment than the UBM machine. Once the appropriate repair/maintenance schedules and kits are acquired most of these challenges should be addressed. Additionally, if the machine is "hard-broken" in the CENTCOM AOR, there is a FrameCAD office located in Dubai with full maintenance and repair capability. The largest hurdle is that this system is new. The other systems have been around for a long time and there are still difficulties in retaining experienced personnel to operate and design for them. The FrameCAD system will have to gain significant support in order to carve out a place in the Air Force's toolbox.
14	8/8		8/8		8/8	

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