

Refining Operational Vertical Mobility

Part 1 of 3

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“Once you see the boundaries of your environment, they are no longer the boundaries of your environment.” – Marshall McLuhan

Operational vertical mobility (OVM) is an increasingly valuable response methodology in the contexts of vertical access, extraction (rescue), and evacuation. As contemporary threats continue to innovate in the shadows of worldwide urbanization, personnel across the response spectrum can expect to execute vertical mobility in environments characterized as *Volatile, Uncertain, Complex, Ambiguous, Threat containing* and *Time-compressed* (VUCA-T²).

A requirement for vertical mobility can occur deliberately but will most likely emerge unexpectedly. Responders therefore cannot rely on the presence of dedicated or highly trained vertical specialists during the dynamic execution of unplanned vertical requirements in VUCA-T² environments. Examples of vertical mobility applications in these environments range from dedicated vertical teams to

minimally trained individuals who have not touched a rope in years.

During the response to the September 11, 2012 attacks on U.S. diplomatic facilities in Benghazi, Libya, a United States (US) military Special Operations Forces (SOF) member executed an improvised vertical extraction under enemy fire. In *Benghazi: The Definitive Report*, Jack Murphy describes how a hastily composed response element evacuated critically injured Americans from a rooftop defensive perimeter, including how “they (SOF) lowered the bodies down with rope they had cut from gym equipment” (Murphy & Webb, 2013). This construction of a lowering system with non-standard yet on-hand materials demonstrates how unexpectedly requirements for vertical mobility can emerge under such VUCA-T² conditions.

A well-televised New York City Fire Department (FDNY) high-rise rope rescue is an excellent example from the fire-service of effective improvisation with on-hand resources. In May 1991, FDNY's Rescue-1 crew extracted two workers trapped in smoke-wreathed windows on the top floor of a commercial office building. Upon accessing the roof immediately above the fire-engulfed 12th floor, Lt. Patrick "Paddy" Brown's crew performed "the most daring rooftop rope rescue in FDNY history" by executing two hasty single-line lowering systems from locations devoid of suitable anchor points. To compensate for the architectural disadvantage, two firefighters held fellow firefighter and default "meat-anchor" Kevin Shea (Fig 1) in place while a rescuer executed a gentle edge transition. Shea produced enough friction to control two-person descents by rigging the rope as a spine-wrap on his harness's carabiner and maximizing its angular contact over parapets. Despite the absence of more preferred equipment, Brown's Rescue-1 crew effectively lowered rescuers to secure (hasty pick-offs) and transfer window occupants to the safety of evacuation crews waiting in 11th floor windows (Ceder1956, 2016) (Fratu, 2020).



Figure 1: FDNY Human - Meat Anchor /
Screen shot YouTube

The preceding examples illustrates how responders, regardless of their level of training, cannot rely on the presence of

specialized personnel or equipment during the dynamic execution of emergent vertical extractions in VUCA-T² environments. Operational vertical capabilities must therefore be adaptive, principle-based, and relatively simple. Introducing complex, complicated, or rote rigging systems into what is likely an already complex response environment rarely contributes to operational success. Successful mission accomplishment in VUCA-T² circumstances often relies on what design-thinking proponents refer to as *iterative problem-solving skills*. As such, fluid environments compel responders to clearly identify the environment's characteristics, appreciate relevant organizational standards and intentions, and adapt organic resources to emerging threats.

Background

Vertical response personnel can execute operational vertical mobility (OVM) by design or accident. Law enforcement tactical units, military SOF, and civilian rescue personnel, such as mountain rescue and wildland firefighter Rapid Extraction Module Support (REMS), operate in non-linear, open-system, and scale-free network-like environments. OVM increases the likelihood of successful vertical response when operating within environmental pathology characterized as VUCA-T². OVM is a context-conscious, principles-reliant, and technique-adaptable framework that contributes to effective non-linear vertical access solutions when lives hang in the balance.

As illustrated by the Benghazi extraction and the 1991 FDNY rope rescue, neither responding teams nor governing bodies can predict the emerging environmental pathology and constraints associated with the next mission. The most effective vertical movement capabilities are tied to

the requirements and context of the response personnel employing them. Part One of this series of articles exposes potential blind spots by examining the tension between compliance and performance in the vertical response domain. This initial article focuses on describing OVM, framing the challenges, demystifying select governing bodies associated with vertical response, and contextualizing relevant physics concepts.

By the end of this series of articles, practitioners will better understand how to balance mission efficiency with adherence to approved standards, enhance system safety factors (SSF) by employing nonlinear science concepts, meet full-spectrum mission requirements by scaling vertical mission load-outs, and incorporate relevant professional qualifications into a tailored Authority Having Jurisdiction (AHJ).

Operational Vertical Mobility: An Introduction

OVM is the unbounded situational exploitation of environmental features, on-hand vertical access equipment, and available personnel. OVM emphasizes deliberate improvisation, iterative processes, and innovative problem-solving in the vertical access, extraction (rescue), and evacuation context. Specifically, OVM integrates elemental problem-solving tools from relevant frameworks, including high

reliability organizing (HRO), systems thinking, and liminal thinking.

Conscious OVM practitioners perform, teach, and create novel vertical response tactics, techniques, and procedures (TTP) for unpredictable high-threat environments. OVM-focused vertical response teams develop adaptive, often novel, and at times divergent rigging solutions. This is accomplished by acknowledging the critical role of context, expecting to operate in non-linear open-system environments, applying Systems Thinking principles, and aspiring to embody HRO characteristics.

What worked in one context with one response group may fail when another group executes the exact same technique in a different context. OVM is neither a “one-size-fits-all” guideline nor convenient aggregation of best practices. Rather, it is a multi-disciplinary vertical response framework that utilizes sound principles encouraging continual improvement. OVM’s response lexicon does not include universal statements and absolutes such as, “never do X” or “always do Y”.

There is no guarantee of a textbook “bomber” anchor, optimal length of rope, or preferred accessory hardware. OVM demands rapid rigging decisions within the context of available organic assets (equipment & personnel), threat level, experience, depth of knowledge, and time constraints.

Framing the Challenge: The Standard for Vertical Operations

“It isn’t that they can’t see the solution. It is that they can’t see the problem.” – G.K. Chesterton

Long-standing (legacy) cognitive processes for vertical mobility are often rendered irrelevant or devolve into the

illogical in a VUCA-T² environment. Irrelevance is often rooted in comparing operational TTPs containing mission-

specific benchmarks to borderline-fictional vertical response gold standards (for requirements). Confusion is the first by-product of what happens when we try to balance adherence to an approved standard with the inherent operational demands of a highly variable, time compressed, and threat saturated operational landscape.

While some look to the fire service as the gold standard, or take their cue from mountain rescue, and others consider relying upon the functionally vacant “rappel master” certification. Researching what might be the “one” perfect standard to which every vertical team must comply often results in disappointingly circular results. Some program administrators want the convenience of a single international standard that dictates a required rope diameter, prescribes techniques, mandates hardware such as carabiners, and provides a convenient universal equipment minimum break strength (MBS). Although non-existent, such a standard could never meet the diverse demands for use within a dynamic operational vertical environment.

Many in the vertical response domain operate under the false assumption that organizations like the National Fire Protection Association (NFPA) dictate such requirements. Many mountain rescue teams, SOF elements, and federal counterterrorism (CT) teams deploy believing the 11-12.5mm ropes and 40kN-rated steel carabiners they are carrying represents compliance with an NFPA mandate.

Misunderstanding and misinterpretation raise perpetual questions. Why are you using fire department technical rescue gear manufacturer standards as the normative?

What about using the lightweight rescue gear used by many mountain, alpine, and expedition rescue teams? Is alpine access and rescue not ‘real’ or “approved” access and rescue? What about using the gear and techniques utilized in canyon or cave rescue? Is there only one ‘right’ way to perform vertical access and rescue?

NFPA acknowledges that certain vertical access and rescue situations meet a critical threshold where “*expected hazards and situations dictate other performance requirements*” (NFPA1983, 2017). These “other performance requirements” may be in the form of gear utilized and/or techniques employed. Although the Benghazi vignette demonstrates initiative and rapid innovation, some of its key elements—such as improvisation—may be neither appropriate nor possible in other circumstances.

NFPA: The Often-Misinterpreted Ally

The belief that NFPA mandates utilizing bulky / heavy gear and antiquated techniques is completely fallacious. Institutionalized beliefs result in cognitive bias and dissonance. Organizational ignorance, and orthodoxy reinforced through the “I was taught this way, so I am going to teach you this way” approach yields misinformation and TTP stagnation. Rather than using an opposing belief system to change beliefs, this article presents data for the end-user to make an informed decision. NFPA as an adaptable and flexible standard is applicable to the widest array of end-users. The following is a basic overview of the relevant NFPA standards for vertical access and rescue.

NFPA 1006: Standard for Technical Rescue Personnel Professional Qualifications

NFPA 1006 is part of the professional qualification series contained within NFPA. Established in 1994, the committee has continually established credible rescuer qualifications without placing unreasonable constraints on the Authority Having Jurisdiction (AHJ). The most significant changes to NFPA 1006 occurred in 2008 when the editors updated the layout of the standard and in 2017, to have it mirror NFPA 1670 by replacing Level I and II rescuer training levels with the Awareness, Operations, and Technician level terminology.

NFPA 1006 is one of the most applicable standards for operational rescue teams within the United States Special Operations Command (USSOCOM), federal and municipal vertical teams. The standard is presented in basic *job performance requirement* (JPR) fashion. The JPR is described and then supported with the requisite skills and knowledge required to meet the requirement. NFPA 1006's potential benefit for SOF and tactical law enforcement is that it does not specify a particular technique or equipment in any of the standards. The standard is flexible enough for instructors and team leadership to adapt their program to the operational environment. For example, Chapter 5 – Rope Rescue, Operations Level, 5.2.6 is the JPR for constructing a multiple-point anchor system (NFPA1006, 2017). While a traditional rope rescue course would likely use 1" tubular or flat webbing slings or a length of rope, the JPR allows for a mountain rescue or SOF team, to construct a multiple-point anchor with mechanical anchor devices, Dyneema® slings, other people, or cordelette.

NFPA 1006 also provides the Authority Having Jurisdiction (AHJ) flexibility in selecting equipment and techniques to complete the JPR. The AHJ is the most critical aspect of NFPA that a team can recognize and apply. The 1006 committee recognizes that NFPA end-users vary greatly across the operational spectrum, and each individual team may have a different equipment need and/or approach.

So, who is the AHJ? You are—or at least, you could be. Although AHJ is often thought to imply local government, leadership, or branch of military, in fact your own team or organization forms its own AHJ. Through its provision of jurisdictional flexibility, NFPA 1006 acknowledges the possibility that no governing organization understands your area of operations (AO), vertical key performance parameters, or potential threat level better than you.

NFPA defines the AHJ within 1006 as follows;

3.2.2 Authority Having Jurisdiction (AHJ). "An organization, office, or individual responsible for enforcing the requirements of a code, or standard, or for approving equipment, materials, an installation, or a procedure" (NFPA1006, 2017).

Forming and integrating one's own AHJ for a team, unit, or organization is critical. There is no reason a law enforcement team must use the same NFPA G-Rated equipment as their municipality's fire department, because someone told them they had to. Law enforcement's response, context, and threat levels dictate distinctively different performance requirements. A law enforcement teams'

individual AHJ could have completely different equipment, TTP's, and system safety factors than their local fire department. It is imperative practitioners take control of their vertical operations by developing their AHJ in accordance with the supporting guidelines.

NFPA 1006 JPR's are analogous to a toolbox because multiple techniques and skills can be employed to accomplish many of the JPRs. This concept is consistent with Yaneer Bar-Yam's research on multi-scale requisite variety (Bar-Yam, 2004). While some of the tools will be used on most rescues, others, based on the discretion of the trained rescuer, may not be applicable.

Although the NFPA does have sample toolkits in the Annex of the standard, they are for information purposes only and are not part of the standard requirement. Depending on how a team's AHJ defines component utilization for vertical response, a SOF vertical team's toolkit may only consist of a 7.5mm bail-out system utilizing a one-way munter as the progressive capture device (PCD) and a nylon runner tied into a Klemheist as the rope grab.

NFPA 1670

NFPA 1670 (2017), is the Standard on Operations and Training for Technical Search and Rescue Incidents. There are a few relevant sections of 1670 worth discussing.

1.1.1 "The standard shall identify and establish functional capability for conducting operations at technical search and rescue incidents while minimizing threats to rescuers."

1.1.2 "The requirements of this standard shall apply to organizations that provide response to technical search and rescue incidents, including those not regulated by governmental mandates."

1.1.3 "It is not the intent of this document to be applied to individuals and their associated skills and/or qualifications."

While the scope is fairly straightforward, it is worth noting that NFPA specifically calls for this standard to apply to any *organization* that provides rescue services to include law enforcement (A.1.1.2). Also, as stated in 1.1.3 of the scope, this does not address the individual skills of a team member, A.1.1.3 reiterates this, "While organizations can meet the requirements of this standard, individuals and their skills and qualifications are outside of the scope of this document and are addressed in NFPA 1006."

As stated in the scope, the primary purpose of NFPA 1670 is to create a system whereby the AHJ can assess technical rescue hazards within the response area and to identify the AHJ's level of operational capability. As an example, when we conduct an evaluation on a team's operational capability, we use NFPA 1670 as a template.

NFPA 1670 depicts operational capability into the distinctive *Awareness, Operations, and Technician* categories.

- The awareness capability is designed to protect untrained personnel by educating them on the hazards associated with a technical rescue incident, identifying the

appropriate resources, and establishing an adequate command system capable of receiving those resources.

- Operations level rope rescue teams may perform high-angle and low-angle rescues to a specific standard such as a haul or raise when the patient is at the height of the rescuers after being carried to the bottom of the vertical face.
- Considering the highest level of capability, technician level teams are capable of performing and managing rescues in the operational zone containing the highest degree of hazards utilizing specialized equipment and
- techniques such as mid-face pickoffs and tensioned rope systems.

While the Chapter 5 standard does not require all team members to be qualified to the operational capability, a team with only one member trained to NFPA 1006 Operations Level will not pass a rope rescue Operations level evaluation. The team must have adequate resources (personnel and equipment) to function at the level they wish to attain.

NFPA 1407: Not To Be Overlooked

As the Standard for Training Fire Service Rapid Interventions Crews, NFPA 1407 also directly correlates to federal CT and SOF vertical teams. The term rapid intervention crew (RIC/RIT) describes a fire service element whose sole responsibility is to rescue their own, i.e. other firefighters who get into trouble. Whether it is disorientation, entanglement, or building collapse, this team deploys immediately and aggressively once any one of multiple

criteria are met, primarily a “mayday” (NFPA1407, 2015) from an interior fire suppression crew.

Due to the extreme circumstances under which these rescues are performed, there is no constraining of the rescuers by rigid standards or practices. The training reflects the capabilities needed to intervene immediately and efficiently during this type of crisis, often with limited equipment and personnel. Incorporating the methodology of this standard is a must for SOF, tactical law enforcement, RTF’s, and REMS units because it enables units to train for a P-A-C-E (Primary, Alternate, Contingency, Emergency) methodology-compliant capability.

NFPA 1983: The Manufacturer’s Standard

NFPA 1983, Standard on Life Safety Rope and Equipment for Emergency Services (2017)

Defines design and strength specifications. Its target audience is life safety equipment manufacturers, as opposed to end users. The standard includes detailed testing and production requirements to ensure compliance. NFPA 1983 is frequently misinterpreted, especially outside of the fire rescue community, and becomes inadvertently utilized to make equipment and training selections outside of the technical rescue environment. In other words, NFPA 1983 is not an end-user standard...it is a manufacturer’s standard.

An important aspect within the scope of NFPA 1983, especially for mountain rescue, USSOCOM, federal response teams, and even fire-based rescue task force teams (RTF) is contained in NFPA 1983 section 1.1.5 which states:

“This standard shall not specify requirements for any rope or associated equipment designed for mountain rescue, cave rescue, lead climbing operations, or where expected hazards and situations dictate other performance requirements.”

In the SOF mission profile, “expected hazards and situations” dictating “other” performance requirements is an everyday occurrence. Current conflicts continue and broaden, more operations are being conducted in mountainous, maritime, and exposed urban environments. These missions require a unique skill set that accounts for ongoing identified as well as emerging threats. This OVM emphasizes incorporating multiple disciplines of access and rescue to include mountain rescue and lead climbing techniques. NFPA 1983 has in the past been misinterpreted as an end-user standard and misused as a requirement for multiple USSOCOM programmatic contracts.

Despite operational limitations, NFPA 1983 provides the end-user valuable insights pertaining to testing standards and manufacturing requirements. NFPA 1983, similar to ANSI (American National Standards Institute) or UIAA (Union Internationale Des Associations D’Alpinisme), also provides respected, external, theoretically unbiased, testing standards for rescue equipment construction and strength. Considering these available resources and their varying applications, the end-user must filter these inputs through the context of their key performance parameters.

NFPA metrics are more significant than the NFPA stamp. There currently exists exceptional equipment on the market produced by respectable manufacturers that is not NFPA 1983 certified or tested.

Barriers include NFPA irrelevance to utilization (e.g. Alpine or mountaineering utilization), gear designed for specific missions (e.g. NFPA 1983 does not cover fall protection in general industry), and economic constraints (a company must pay to have the NFPA stamp placed on its individual gear, thus increasing the price to the end-user). For example, both the Edelrid Spoc (*Figure 2*) and the Wild Country Ropeman 2 (*Figure 3*) are utilized extensively in the climbing, mountaineering, and canyoneering access/rescue communities. But despite providing an extremely valuable (and safe) capability in the operational environment, do not have a NFPA 1983 certification.



Figure 2: Edelrid Spoc / Edelrid website

Though an NFPA-certified product may be desired for certain applications, that certification may be neither practical nor relevant for specific mission profiles. In some cases, highly qualified practitioners seek out the UIAA certification for most of the hardware choices they make. When evaluating the most commonly used vertical equipment within USSOCOM climbing teams, for example, the majority is UIAA/(CE) marked hardware.

End users should be familiar with basic material science to include various rope fibers, the advantages and associated caveats of commonly used metals, and the reality of minimum break strength when rigging a system. It may be helpful to recall that NFPA 1983 explicitly states it “*shall not*

specify requirements for any rope or associated equipment where expected hazards and situations dictate other performance requirements.”



Figure 3: Wild Country RopeMan2 / WC

For example, if common working environments for a team require low-weight and minimal rigging time as the most important gear parameters, then they may consider researching smaller diameter ropes with specific higher end fibers. Or if a team focuses on maritime, CBRN, or subterranean arenas, they may be more interested in rope fibers such as Innegra™ which are hydrophobic, lightweight, and chemical resistant (*Figure 4*); whether or not they are included within 1983 or UIAA. Very often, the most successful teams are those which have assumed ownership of their gear evaluations and taken on the responsibility of self-jurisdiction for material selection.



Figure 4: North American Rescue Olympus Rope w/ Innegra Core / NAR website

UIAA (Union Internationale des Association d’Alpinism)

Since its founding at a 1932 alpine congress in France, the International Mountaineering and Climbing Federation (UIAA) has spearheaded the “study and

solution of all problems regarding mountaineering.” According to its website, the UIAA fulfills its worldwide mission “of advancing safe and ethical mountain practices” through its commissions’, recommendations, policy setting, and advocacy. The UIAA has developed a universal climbing grade system, equipment safety standards, training standards accreditation, and the Mountain Medicine Diploma (www.theuiaa.org/about/).

The UIAA is often associated with its Safety Commission’s internationally recognized Safety Label seen on mountaineering equipment. The Safety Commission endeavors to minimize accidents in mountaineering and climbing by developing standards for equipment, analyzing the market to determine standards revisions, reviewing mountaineering and climbing accidents, and accrediting laboratories that test mountaineering and climbing equipment. As many of the largest equipment manufacturers follow the Safety Commission standards, this Commission assesses if existing standards are keeping pace with technology by employing an evidence-based review of mountaineering and climbing accidents.

OVM practitioners can find many updated PDF documents on the standards and testing parameters for mountaineering and climbing equipment on the [UIAA - Safety Standards](#) section UIAA’s website. These documents thoroughly explain strength and operational requirements as well as specific laboratory test protocols. The UIAA collaborates with a partner standardization organization called CEN (EN) to reduce multiplicity and end-user cross referencing. While EN standard references the original UIAA standard, in

some cases the UIAA will have more stringent requirements than those in the EN equivalency (i.e. UIAA 101).

Like NFPA 1983, UIAA has limits concerning equipment it certifies for testing. For example, UIAA does not certify

ropes containing material with very low elongation classified as ultra/super static. Aramids are an example of a super static fiber and aramid-sheathed ropes are common in a variety of rescue disciplines due to their inherent strength, higher melting point, and abrasion resistance.

A Word on Safety Factors

It is better to understand little than to misunderstand a lot.

— Anatole France

NFPA System Safety Factors (SSF) are routinely misrepresented and can appear confusing. Usually depicted as a ratio, an SSF is the overall safety factor once all system components are in place, connected, and/or tied. Despite widespread attribution of SSF to NFPA 1983, the document's section A.5.2(6) explicitly states, "NFPA does not establish or endorse a particular safety factor or ratio." The committee on professional qualifications (NFPA 1006) recognizes that only the AHJ can identify its technical rescue team's operating parameters.

A rescue team operating solely in an urban low angle environment may have the luxury of a 10:1 SSF. As the rescue moves into a high-angle rural environment, or as the tactical threat level increases, that SSF could be lowered to 5:1 (or less). From a manpower perspective, a brigade/regimental size element may state a 7:1 SSF, while the operational constraints associated with a fire-team size or reduced-signature element may allow a lower SSF. Considering operational

demands and environmental constraints, OVM practitioners maintain response flexibility by allowing for a range of rigging solutions within the SSF spectrum.

System Safety Factor (SSF) is derived from engineering. In some cases, they have been used effectively, while at other times they have been mindlessly adopted as a substitute for knowledge. Before an organization settles on a 10:1 SSF for all systems, it would be well-served to consider the following:

- Will your environmental anchors always allow support of this SSF?
- Is the requisite time, equipment, and complexity worth a 10:1 SSF?
- Not including weight removed from anchor force due to edges and contact points, the most force one can place on a rappel system is double one's body weight.
- Many SSFs consider the worst-case scenario for a system, such as dynamic loading resulting from a problematic edge transition. However, in many cases the

selection of an alternative technique can exponentially reduce the loading and therefore decrease the possibility of compromising a system. In the case of the edge transition, example techniques that mitigate the edge include hard versus soft starts, lowering the artificial high directional height, and/or inputting force limiting techniques into your system design.

Thought leaders in the vertical response arena have long considered risk mitigation during rope operations. Based on significant testing and evaluation, the Emergency Management British Columbia (EBMC) and the British Columbia Search and Rescue have adopted significant changes within their rope rescue techniques and protocols. These organizations have replaced the 10:1 SSSF requirement by instead utilizing engineered systems with a minimum 20 kN breaking strength and force-limiting capabilities (Mauthner, 2016).

The SSF issue highlights the difficulty in applying “civilian” standards en bloc to the operational environment. NFPA 1983 is often incorrectly cited as requiring a 15:1 SSF. This is only true for the safety factor (SF) of a “G” rated Fire Department life-

safety rope, because a 1/2” rope has a required breaking strength of ~9,000 lbs (40kN) (NFPA1983, 2017). The standard’s original authors believed a 600-pound load was typical of a two-person rescue, including patient, rescuer, and equipment. One can use division to calculate a 15:1 safety factor which, unlike an SSF that applies to the entire system, is a hypothetical number that only applies to an unknotted rope. Unless a manufacturer wants to sell a rope with an NFPA 1983 “G” Rating, this potential 15:1 safety factor does not apply and does not reflect the safety of a vertical system.

In contrast with the potentially (and inadvertently) inflated SSF values seen in practice by rope-rescue and climbing professionals, the safety factor for the commercial aviation industry is 1.5:1. The safety factor for human space travel is 1.4:1. These advanced industries have presumably applied fundamental expertise in the areas of engineering analysis, nonlinear physics, and redundant safety in order to reduce the level of over-building. It stands to reason that the vertical mobility community could at least begin to move in that direction through a thorough comprehension of full spectrum application.

Background Information for Equipment Selection and TTP Development

Very often it is familiarity that gives the illusion of simplicity and leads to misunderstandings.

— Bruce J. West, Simplifying Complexity

OVM practitioners understand that neither the vertical team nor any governing body

can predict the environmental pathology and constraints which will govern the next

mission or call-out. When the need arises for vertical access or rescue, the response team will have what they have, and the environment will give them what it gives them. Practitioners accustomed to making the best with what they have often innovate novel solutions “on the fly” thru using deliberate improvisation and systems thinking, as well as liminal thinking.

This information is for OVM practitioners who routinely engage undefined/unstructured problems in the disorder of the VUCA-T² environment. Dynamic incident response, including OVM, is not in the job scope of those operating in linear environments. Such relatively structured environments are characterized by clean categorization of elements, clear cause and effect, proportional input-output, algorithm or probability reliance, and defined circumstances.

As the OVM workspace is constantly changing and evolving, practitioners must embrace its inherent nonlinearity, complexity, and chaos. What works in one situation may implode elsewhere. OVM practitioners strive to constantly adapt while avoiding sole reliance on any single TTP or methodology. Since the OVM working environment is sensitive to initial conditions, practitioners should feel comfortable jettisoning any TTP that doesn't fit the situation. They can immediately call an audible and reduce vulnerability to cognitive dissonance. Consider the advice of Neil McCauley played by Robert De Niro in the 1995 film *Heat*: “A guy told me one time, don't let yourself get attached to anything you are not willing to walk out on in 30 seconds flat if you feel the heat around the corner.” As opposed to seeking a “best practice,” practitioners wield forged principles capable of affecting change in any situation. Best practices will naturally

emerge within an incident's context and the unique variables of the operation.

Linear vs. Nonlinear Systems: The Basics

Linear systems are clean, orderly, and inspire confidence in those listening to a “linearized” operational brief. These briefs use defined Gaussian probabilities to describe success, predictiveness, and risk. They use a Categorization model to generate a clear (albeit potentially fictitious) correlation between cause and effect. In this case, the framework precedes the data. Too often this results in misspecification, misestimation, and misunderstanding of critical information to force it into a predesignated category. In contrast, nonlinear systems are often considered intimidating due to its contact and interaction with an uncertain environment. Nonlinear briefs also do not inspire the same confidence as their linear counterparts due to their unpredictability and lack of clear cause-and-effect correlations. Nonlinear mission sets utilize a Sense-Making model where the data precedes the framework. As a result, it more often opens otherwise narrow perspectives, reduces cognitive bias, and softens habit / functional fixedness.

OVM practitioners who grasp both systems governing principles (*Figure 5 vs. Figure 8*), can operationally leverage them and recognize when they are appropriately applied to the context (or not). Bruce West supports the assertion that linearity appears easier to recognize than nonlinearity when he noted, “Nonlinearity is one of those strange concepts that is

defined by what it is not” (West, 2013).

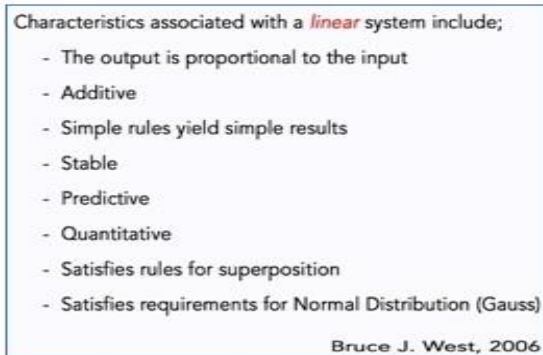


Figure 5: Linear System Characteristics / Image Element Rescue

In linear systems, variables are independent, understandable, and able to be solved once isolated from the system. They are innately predictive, stable, and often considered a trivial problem. Conversely, nonlinearity contains inherently interdependent and interactive variables (agents). Complexity is nonlinear, originating from the Latin word *complexus*; *com-* “together” and *plecture* – “to weave” or “braid”.

The nonlinear behavior is derived from these variables interacting in diverse ways, each influencing the others and in turn being influenced by their responses. This creates an unpredictable or unique feedback at both microscopic and macroscopic levels (Strumberg, 2015). These systems are inherently unpredictable, unstable, quantitative and qualitative, and meet the requirements for power-law distribution (Pareto) vs. Gaussian normal distribution (West, 2006). Work in a nonlinear system or environment is associated with occupations that demand interaction with the “real-world” environment outside of a laboratory or administrative office. The environment contains critical information which can only be revealed through engagement by the on-scene responders.

In addition to being linear or nonlinear, a system can also be open or closed. These two descriptors of system *sense-making* are mutually complementary. In a closed system, outside influences can be ignored (Rickles, Hawe, & Shiell, 2007). These exogenous variables may be the environment (including behavioral, physical, or physiological threats), or what Norbert Wiener refers to as “noise” in his signal-plus-noise paradigm. Due to this exclusion capability and/or criteria, closed systems are innately linear in nature.

Open systems, on the other hand, are those that are not or cannot be screened off from their environments. Most real-world systems and operational maneuvering are open systems. This presents problems for modeling, planning, and experimenting on such systems - because the unpredictable effect of exogenous influences (environmental pathology) must be taken into account. “Noise” cannot be ignored in these systems due to it potentially carrying critical information and insight (West, *Where Medicine Went Wrong, Rediscovering the Path to Complexity*, 2006). These influences can be magnified over time by sensitivity to initial conditions (Rickles, Hawe, & Shiell, 2007) (Mobus & Kalton, 2015).

Newtonian physics and its associative equations are often inherently linear. Practitioners typically use these equations and laws to solve problems ranging from velocity and vector analysis to mechanical advantage systems of simple machines. If used within the proper context, this usually works well for systems that satisfy the requirements for reductionism or superposition (West, 2006).

Examining mechanical advantages used in rope rescue through the lens of Newtonian physics can, upon the introduction of a simple, single environmental (exogenic) variable into the system, illustrate where and how nonlinearity's characteristics emerge. Consider the following example:

Given the task of constructing a rope rescue haul system to retrieve a casualty, a team elects to employ a 3:1 simple mechanical advantage (MA) haul system. The team knows it is a 3:1 MA because the tensions can be counted in the system rigging using principles of Newton (*Figure 6*). Upon confirming the MA is a 3:1, the team can then divide that out with the estimated weight of the load (casualty) and calculate how much force is required to raise the load/casualty. While this appears to work well in a textbook's iterative equations or on a whiteboard, such applications fail in the environment or when tested with load cells. This is because the claimed 3:1 MA, is a theoretical number (ElementRescue, 2020).



Figure 6: Counting Tensions / Element Rescue

The theoretical number does not account for any friction within the system resulting from pulleys or edges. Pulleys all contain friction and are estimated by manufacturers as efficiencies. A sealed bearing pulley

may state an efficiency of 90%, meaning the user is only losing 10% to the internal friction of the pulley. A pulley manufactured using a bushing construction may have an efficiency of 72% in which the user is losing 28% efficiency to internal pulley friction (ElementRescue, 2020).

This proverbial rabbit hole goes down even deeper when one learns how manufacturers estimate this efficiency--by using one specific diameter of steel cable. Manufacturers had to produce a standard so efficiencies would not vary across the broad spectrum of rope manufacturing techniques and materials. Some rope has a softer hand, meaning it may become flatter when larger loads are applied, which sets in motion a series of downstream and tangential issues. The flatter rope can lose greater efficiency through the pulley due to it spreading over the sheave or because of the coefficient of friction of the material. The same can be said to how it bends over the edge or edges it comes in contact with between the anchor and the load (casualty).

When examining the impact of efficiency loss of a 3:1 Simple MA as a result of just the internal friction within the pulleys, the MA would be approximately a 2.7:1 when using 90% efficient pulleys. This does not include any edge friction or friction produced from the load interacting with the wall or ground in which it is being raised. When using a Gri - Gri 2 as a progressive capture device (PCD) and a carabiner without a pulley on the rope grab, the estimated MA is reduced to approximately a 1.6:1 (*Figure 7*) (ElementRescue, 2020).

Operationally, practitioners, at best, estimate these numbers dealing with friction due to the large variabilities including rope manufacturing (bending

rigidity), rope material, and the various coefficients of friction (COF) of any part of the system coming into contact with any part of the environment (Jung, Pan, & Kang, 2008). This is the unpredictability of nonlinearity (West, 2006) (ElementRescue, 2020) (Jung, Pan, & Kang, 2008). In the above example, only one of multiple real-world variables were inputted. So when Rich Carlson, considered by many to be the leading authority on contemporary canyoneering is asked the question, "If a team is setting up a mechanical advantage, and not using any edge rollers, what is the MA?" his answer is usually, "It depends" (Carlson, 2017). In fact, the answer depends on a multitude of other variables, often referred to as environmental pathology.

Environmental Pathology: A Closer Look

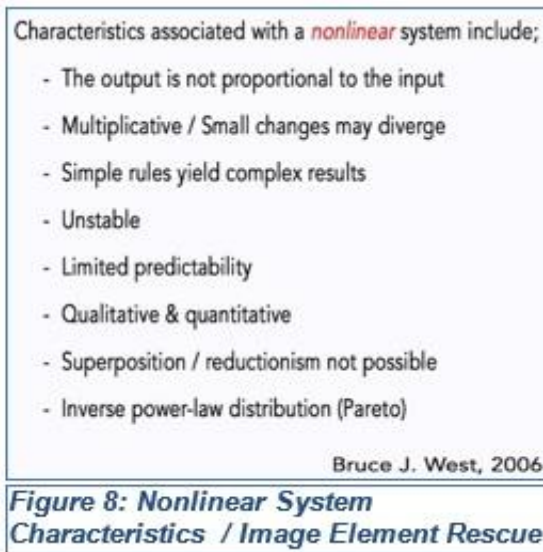
The term *pathology* is most often associated with the domain of casualty care, specifically a prehospital setting wherein providers do not diagnose but rather rapidly identify and intervene utilizing a feedback loop. This casualty pathology may take the form of penetrating trauma, traumatic brain injury, or various disease processes. Pathology has its roots in ancient Greece from *pathos*, meaning "experience" or "suffering" and *-logia*, meaning "study of". Definitions span the spectrum from "deviations from normal that constitute disease", "deviations giving rise to social ills", to the ambiguous "something abnormal".

It is critical that OVM practitioners recognize that the environment also provides its own pathology. In other words, the environment always has a say. This pathology can take the form of a behavioral or physical threat, weather conditions, topography within the area of operations

(AO), enemy disposition, or adjacent supporting units. When these two pathologies become interdependent, the environment typically becomes the comorbidity to the casualty pathology (van Stralen, McKay, Williams, & Mercer, 2018).

For special operations, the environment is an ever-changing nearly animate entity that demands understanding, adaptation, and non-linear thinking. A rescuer, operator, or first responder cannot blindly accept what may have successfully worked in previous circumstances to produce the same positive result in the circumstance at hand.

OVM practitioners develop an appreciation for their operational vertical system's topography, in a manner akin to how a network is mapped. The topography examines operational uncertainties like emerging variables, bifurcations, and possibilities. The more accurately practitioners understand a given topography, the fewer blind spots they will encounter operationally (West & Scafetta, 2010). The concepts presented in Part One of this series provides some of the foundational components to mapping out mission topography with the remainder of these tools being presented in Parts Two and Three. To avoid the descent into linear predictive optics and probabilities, the best OVM practitioners simply accept and embrace the ill-defined problem existing in the unstructured environment and train accordingly.



Part One: Conclusion

There is a time and place for clearly stated TTP's, engineered from relevant JPR's of accepted standard(s). The best of these TTP's are written in a loose-coupled format, allowing the practitioner to adapt rigging styles to the environment. These standards must be tested, proven, and heavily researched, or they can produce unneeded constraints on the response team. Traditionally, studies for standards are derived from problem sets repeatedly encountered in the operational and VUCA-T² environments. Too often they have been isolated from the environmental pathology and implanted into the comfort of laboratories and research facilities attempting to produce binary responses for application in the field.

In contrast, OVM interactive TTP development contradicts traditional design principles. Theories are created out of practice as opposed to putting theories into practice. It is during these developmental iterations where we integrate nonlinear principles, divergent problem solving, and mindful improvisation to create novel solutions for JPR standards. It is with the integration of an efficient AHJ that we are

able to mold and reverse engineer the "guideline standards" in order to apply them to the non-standard problems that inevitably emerge within the operational environment.

Before we find ourselves in an operational environment like the Benghazi rooftop, this process starts with establishing frameworks for flexible equipment selection and TTP development. Equipment is selected based on its ability to efficiently perform its intended task, adaptability to perform other tasks within a vertical system, ability to complement existing components, and capability of withstanding projected environmental durability and human factors variables.

Adherence to and development of TTPs can be approached with similar frameworks. Reminiscent of seafaring "pirate code", they are loosely coupled rules that are followed--until they aren't--or at least until they are no longer relevant to operational success. They must be written and practiced in such a way that they permit adaptation to the known knowns, the known unknowns, and most importantly the unknown unknowns – those emerging outlier perturbations where "we don't know what we don't know" (Rumsfeld, 2002).

These "unknown unknowns" are the operational sucker punches too often highlighted and underlined in after action reports. The information, science, and thought processes presented throughout this series of articles are presented to promote the development of OVM design in a systematic, organized, and mindful manner. The result can be a robust antifragile – operationally reliable framework for individuals and teams operating in a VUCA-T² environment. An OVM-conscious response team will, when

the need arises, employ novel solutions by exploiting organic assets, environmental resources, and adaptive rigging design.

Part One reinforced how mission success in OVM hinges on executable vertical capabilities that enable responders, regardless of their confidence or preparation to enact novel solutions by leveraging organic assets and adaptive rigging design. Part Two will introduce the planning and preparation aspects of OVM, specifically how to integrate HRO principles, heuristics, scale-free networks, and requisite diversity into vertical response systems.

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