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Applying Resilience Theory to 'Bounce Forward' from COVID-19 for Environmental Engineering Programs

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The COVID-19 pandemic has disrupted higher education in numerous ways. As COVID-19 spread worldwide in the spring of 2020, most colleges and universities closed their campuses and transitioned to remote learning platforms. As uncertainty surrounding COVID-19 persisted into 2021, many colleges and universities continued to employ remote learning or transitioned to hybrid in-person / remote learning approaches to prevent further outbreaks on campuses. While COVID-19 has been devastating, we propose that the pandemic also presents an unprecedented opportunity to reflect, reassess, and 'bounce forward' to become more efficient, effective, and resilient. The National Academy of Sciences' definition of resilience has spurred a theory of resilience that centers on four successive stages surrounding a disruptive event, such as COVID-19: (1) plan and prepare, (2) absorb, (3) recover, and (4) adapt. In this paper we propose a framework that environmental programs can employ to 'adapt' (stage 4) and 'bounce forward' to a more resilient modus operandi long-term. The framework first identifies each activity a program executes, and then bins them into one of four categories based on importance relative to the program's outcomes: critical, essential, enhancing, or ancillary. Critical and essential activities are those that are necessary to achieve the program's educational outcomes and remain ABET compliant, or those that directly underpin and enable achievement of outcomes and accreditation, respectively. Enhancing and ancillary activities are those that substantially elevate or noticeably enhance, respectively, a program's educational experience; however, if they are not executed, do not result in a failure to achieve a program's educational objectives. Once activities are identified and binned, opportunities for 'bouncing forward' are identified and explored. While the results of this assessment will inevitably look different for each environmental engineering program, our program found opportunities to immediately 'bounce forward' in several areas, to include integrating remote teaching and distance learning best practices and streamlining administrative practices. We also identified opportunities to 'bounce forward' over the next three to five years, to include eliminating low payoff activities and reassessing the way we do laboratory work. However, continual clear-eyed self-assessment is required to fully realize the 'bounce forward' opportunities available post-pandemic.

"Never let a good crisis go to waste."

– Winston Churchill

1. Introduction

The COVID-19 pandemic caused substantial disruption to systems and organizations worldwide. As COVID-19 spread worldwide in 2020, most colleges and universities closed their campuses and transitioned to remote learning platforms (Gillis & Krull 2020; Lederman 2020). As uncertainty surrounding COVID-19 persisted, many colleges and universities continued to employ remote learning or transitioned to hybrid in-person / remote learning approaches to prevent further campus outbreaks (Aguilera-Hermida 2020; Anstey et al. 2020).

Although COVID-19 has been devastating, we propose that the pandemic also presents an unprecedented opportunity to reflect, reassess, and 'bounce forward' to become more efficient, effective, and resilient. This study presents a program-level response to the COVID-19 pandemic using a resilience theory framework. The approach used in this study has provided our program a clear-eyed assessment of our activities and their relative contributions to our desired program and ABET-related outcomes. While results of this study will take years to implement and fully assess, our program has begun to 'bounce forward' towards a more resilient baseline where we are stronger, more prepared, and better positioned to address future disruptions.

2. Resilience Theory

Foundational concepts of resilience theory are employed in numerous and diverse areas of study, including cybersecurity, psychology, ecology, health, energy, and engineering (Eisenberg et al. 2014). The National Academy of Sciences (NAS) defines resilience as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events" (National Research Council 2012). Accordingly, a system will experience four successive states when disturbed or disrupted: (1) prepare and plan, (2) absorb, (3) recover, and (4) adapt (Linkov et al. 2013). Figure 1, derived from Linkov et al. (2014), depicts the four stages for any system, or critical function, over time in response to the COVID-19 pandemic. While this study defines the critical function as "program-level activities", this construct can be applied to systems or functions at numerous scales, to include academic courses, research activities, department-level activities, institutions, etc.

As shown in Figure 1, the initial horizon line along the x-axis describes baseline functionality for the system or function. When a disruptive event occurs, e.g., COVID-19, the system will initially experience reduced functionality as it absorbs disruptive impacts (Step 2). The total reduction in functionality can be expressed as a decrease along the y-axis, with a deeper curve representing a greater impact from the disruptive event and a greater loss of functionality. If the system is unable to absorb the impacts of the disruptive event, then the system may fail. This "maximum deviation from baseline" is shown as a horizontal dotted line along the x-axis of Figure 1. As the system or function recovers, a temporary 'new normal' is established, while those responsible

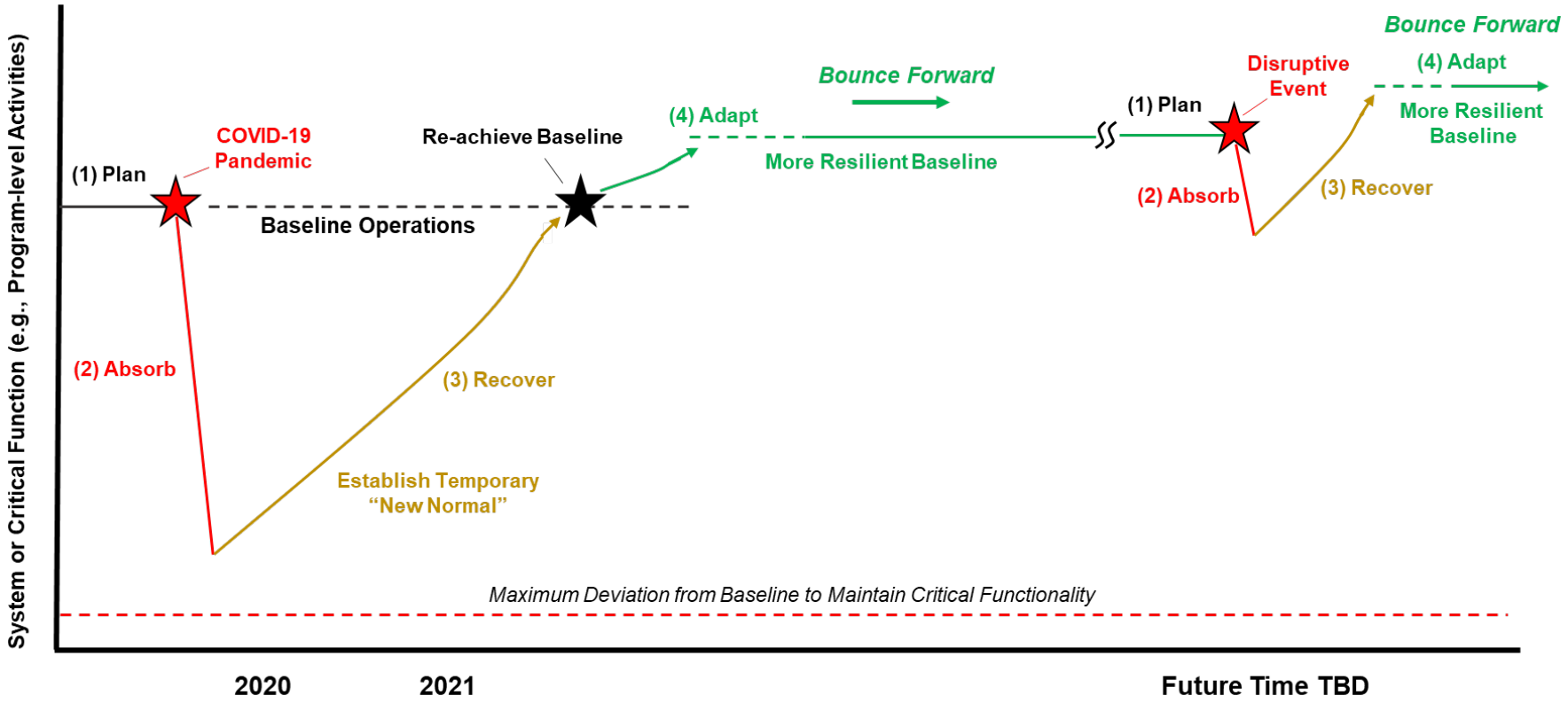

Figure 1. Resilience theory applied to the COVID-19 pandemic for higher education. Response steps to the 'black swan' event are depicted using different colors (i.e., Step 1 (Plan) is black; Step 2 (Absorb) is red; Step 3 (Recover) is gold; and Step 4 (Adapt) is green). The response by most institutions of higher education to the COVID-19 pandemic in the spring of 2020 was considered 'high risk, low resilience'. This response type is depicted in the left side of the figure and is signified by a relatively substantial loss of functionality (Step 2: Absorb) and a long recovery time (Step 3: Recover). A more resilient baseline is depicted in the center of the future with the term 'Bounce Forward'. Also shown, on the right side of the figure, is a more resilient response posture, i.e., a 'high risk, high resilience' response. This response is signified by the ability to absorb the impacts of the disruptive event, less loss of critical function, and a relatively quick recovery period. Of note, although this figure depicts a flat horizon line for each 'more resilient' baseline (indicated in green), an institution can elect to achieve an ever-increasing resilience posture that can quickly and effectively respond to both minor perturbations and major disruptive events.

for recovery efforts implement short-term measures to aid in recovery. The slope and length of the recovery curve (Step 3) along the horizon line indicates the temporal effects of the disruptive event on the system. A short, steep recovery curve suggests a relatively quick recovery from the disruptive event, while a longer recovery curve suggests increased recovery time.

This resilience model assumes that the pre-disturbance level of functionality can be achieved after recovery; however, that may not be the case for all systems. Some systems may be permanently damaged and can never return to the pre-disturbance level of functionality. However, if pre-disturbance functionality is achieved, the goal should be to adapt (Step 4) and become more resilient. System leaders should reflect and capture lessons learned. Doing so can inform establishment of a more resilient baseline as the system 'bounces forward' from the disruptive event.

3. Resilience Posture of Higher Education – Impact of the COVID-19 Pandemic

Most colleges and universities exhibited a 'high risk, low resilience' response to the COVID-19 pandemic (depicted in Figure 1). The COVID-19 pandemic is a 'high risk' (high-impact, low-probably) event that caused considerable disruption. Another name for such an event is a 'black swan' event. 'Black swan' events, although rare, often exert disproportionately severe and catastrophic impacts upon critical systems and functions (Sikula et al. 2015). Further, prior to COVID-19, most institutions were in a 'low resilience' response posture for a global pandemic. Few institutions of higher learning had a robust plan for continued operation during pandemic lock-down. Instead, for most institutions, the COVID-19 pandemic substantially disrupted routine operations over an extended timeframe.

In a 'high risk, low resilience' response scenario, the absorb curve (Figure 1, Step 2) dips deep along the y-axis. For many colleges and universities system functionality on numerous levels (e.g., course, program, department, or institution) rapidly decreased as each absorbed the disruptive impacts brought about in the spring of 2020 when COVID-19 cases increased, and the World Health Organization declared the disease a global pandemic (Cucinotta & Vanelli 2020). Despite the extreme impacts of the COVID-19 'black swan', most institutions did not exceed a maximum deviation from baseline functionality and instead began to immediately recover (Figure 1, Step 3). During recovery, execution of formerly routine events can be substantially degraded and require extensive additional planning and resources. To continue functioning during the recovery period, most colleges and universities established a 'temporary new normal' by employing remote teaching platforms and distance education approaches (Daniel, 2020; Ortiz, 2020; Barron and Alzoubi, 2020). For example, our university, the U.S. Military Academy at West Point, leveraged the Office365 software suite, specifically Microsoft Teams, as well as virtual classroom capabilities in BlackBoard, our university's learning management platform, to connect with students remotely. Fortuitously, West Point had just completed a multi-year information technology transition in 2019, which provided robust and resilient IT infrastructure capable of handling the demands of online instruction.

Due to the widespread impacts of COVID19, most colleges and universities still find themselves on the recovery curve (Figure 1, Step 3) at the time of this study. In some ways, aspects of the 'new normal' that institutions established in the COVID-19 environment will not be 'temporary'

but will instead become routine. The COVID-19 recovery period provides us opportunity to reflect and rethink activities. As institutions begin to return to pre-pandemic conditions, we have a unique, perhaps once in a century, opportunity to critically examine the way we do business and create a more resilience post-pandemic future.

4. Opportunity to 'Bounce Forward'

According to the resilience theory presented by Linkov et al. 2014, the post-pandemic recovery will include adapting to the new environment. During this step, a system or function can 'rebound' to the previous baseline, or those responsible for the system can actively pursue measures to enhance system resilience. Such measures can include integration of new technologies, new policies or approaches, purchase of new equipment (e.g., automated sensor networks), or the use of adaptive materials (Linkov et al. 2014). We call the movement to enhanced resilience 'bouncing forward'. As the name suggests, 'bouncing forward' indicates movement to and adaptation of a greater level of functionality, and a new, more resilient baseline. The ability to 'bounce forward' is enabled by appropriate resources and the wise application of lessons learned (Wied et al. 2020). The goal should not be a speedy recovery to pre-existing baseline conditions, but instead thoughtful and deliberate movement to a higher and more flexible level of functioning.

Figure 1 also depicts a more resilience response to a future 'black swan' event, which could include another pandemic, a major conflict, a major terrorist attack, a significant natural disaster, or a drastic budget cut. Here, the system response is 'high risk, high resilience' stemming from a more resilient post-COVID operational baseline. In this future scenario, the system, along with partner agencies and institutions, measures new information in the environment to identify disruptive event indicators. When a disruptive event occurs, the more resilient system minimizes the disturbance basin and maintains a high level of critical functionality. Recovery is swift. The system quickly adapts and applies lessons learned to achieve an even more resilient baseline from which to accomplish its principal goals.

'Bouncing forward' can be a transformative experience – one that allows the system to become more psychologically resilient, operationally effective, and capable of responding to unforeseen challenges. While many eagerly anticipate a return to normalcy (i.e., pre-disturbance conditions), the time is ripe for mindful, deliberate assessment of individual and collective activities and their relative contribution to the system's goal.

5. Methods for Program-level Assessment

We propose a six-step process for 'bouncing forward' at a program level (Figure 2). The process begins with taking stock of current program-level activities by identifying and categorizing each into major functional categories (Steps 1 and 2). Part of this approach is to identify who is responsible for each activity, which may not be readily apparent. Proposed major functional categories are found in Table 1.A. Once activities are identified and binned, then each are classified as 'critical', 'essential', 'enhancing', or 'ancillary'. Definitions of each classification are found in Table 1.B. After classification, each activity is examined considering COVID-19 impacts, i.e., was the activity modified during the pandemic? If so, was the change positive or negative? Further, does the change represent an opportunity to 'bounce forward' and enhance

resilience (Step 5)? The individual responsible for the activity is likely in the best position to answer these questions. The last step (6) is implementation, which can include making changes permanent, synergizing like efforts, and creating timelines for execution.

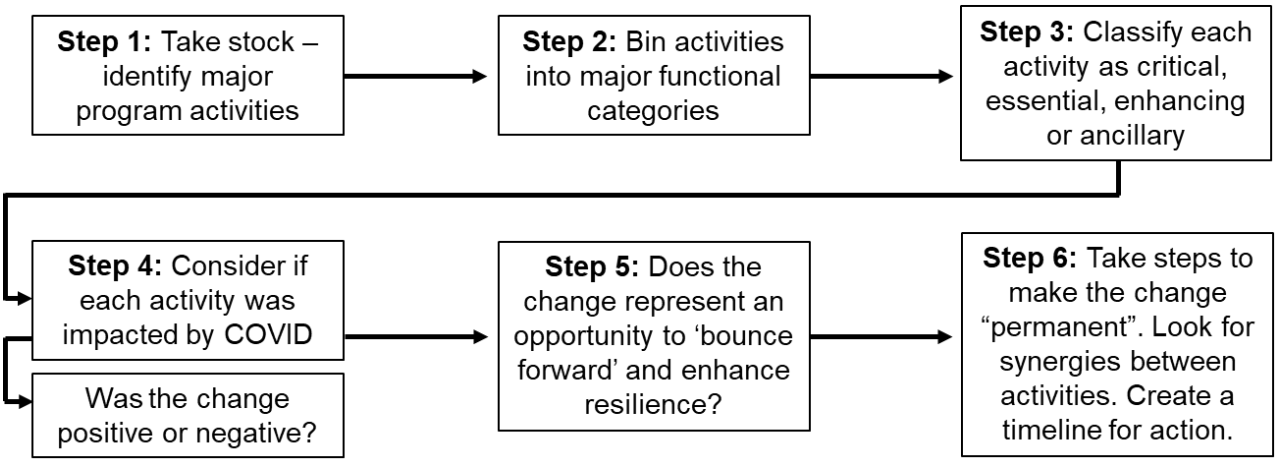

Figure 2. Six-step process for assessing activities at a program-level.

Table 1. Key Categories and Categorizations for Program-level Assessment. (A) Several possible functional categories developed in this analysis. (B) Definition for each classification category.

(A) Possible Functional Categories for Activities

- Assessment & Accreditation
- Communication
- Faculty Development
- Lab
- Leadership & Service Responsibilities
- Research
- Student Development
- Teaching

(B) Classification Categories

- **Critical.** Core activities that are absolutely necessary to execute the program's objectives and achieve desired outcomes.
- **Essential.** Supporting layer of activities that directly enable the execution of core activities and are therefore absolutely necessary. e.g., critical activities cannot be accomplished without essential activities.
- **Enhancing.** Activities that elevate program objectives and desired outcomes by facilitating an more optimal developmental experience, but the loss of which does not result in loss of critical functionality.
- **Ancillary.** Activities that may enhance program objectives and desired outcomes, but are secondary and not required to achieve critical functionality.

6. Program-level Assessment Results and Discussion

The following sections provide results and discuss findings from our environmental engineering program-level analysis using the six-step approach described in Figure 2 and the functional and classification categories presented in Table 1.

6.1. Environmental Engineering Program Major Objectives

To provide an accurate classification (i.e., critical, essential, enhancing, or ancillary), we examined each activity considering our program's major objectives and desired outcomes. Major objectives can be derived from our program-level vision: "inspire and develop students, faculty, and staff regarding current environmental issues and potential solutions through outstanding teaching and scholarship in a professional and collegial environment". Necessary to successful accomplishment of our program mission is ABET accreditation. Further, our program is responsible not just for our environmental engineering major, but for the administration of a sequence of three environmental engineering courses offered to students outside of our major. This engineering sequence helps students meet institutional graduation requirements. Therefore, our major objectives are:

- Educate and inspire students through outstanding teaching and mentorship to be leaders of character.
- Develop faculty and staff.
- Develop solutions to environmental issues through outstanding research and scholarship.
- Create a professional and collegial environment.
- Maintain ABET accreditation.
- Successfully administer our environmental engineering major and our environmental engineering sequence.

6.2. Activity Assessment

Following the six-step process described in Figure 2, our program identified 60 recurring activities. Table 2 provides a list of all activities (Step 1), the major functional category for each (Step 2), the classification for each (Step 3), whether the activity was impacted by the COVID-19 pandemic (Step 4), and whether the change represents a 'bounce forward' opportunity (Step 5). Results for Step 6 (taking steps to 'bounce forward') are discussed in subsequent sections for several activities, and one course-level example, that we determined may be most useful for other institutions.

As shown in Table 2, of the 6 functional categories, the one with the most activities was 'Student Development and Services' with 14 activities. We identified 6 to 12 activities in each other category, except for 'Communication', which had only 3 major activities. Of the 60 identified activities, we deemed 16 as 'critical', 12 as 'essential', 19 as 'enhancing', and 7 as 'ancillary'. Another 6 activities were identified as positions (e.g., Program Director) and were not classified further. We identified 'critical' and 'essential' activities in each category; however,

Table 2. Major activities for the environmental engineering program at our university. Within each major activity, various supporting activities were also identified (for brevity, not all supporting activities are listed). Major activities are grouped by category and classifications (according to definitions in Table 1B) are provided. Also listed is whether the activity was impacted by the COVID-19 pandemic and if the change is an opportunity to 'bounce forward'. For brevity, information is listed as "yes", "no", "TBD" or "N/A". In cases where the event was cancelled or simply delayed no other impact, the word "cancelled" or "delayed" were recorded.

Category	Activity	Classification	Impacted by COVID-19?	Opportunity to Bounce Forward?
Assessment & Accreditation	ABET Reaccreditation	Critical	Yes	No
	Program Educational Objective Assessment	Critical	No	N/A
	Course Assessment & Annual Reports	Critical	Yes	Yes
	ABET Board of Advisors Visit	Essential	Yes	Yes
	Program-level Assessment & Executive Summary	Essential	No	N/A
	Graduate Exit Survey	Enhancing	Yes	TBD
Teaching	Environmental Engineering Course Management	Critical	Yes	Yes
	Core Engineering Sequence Course Management	Critical	Yes	Yes
	Grading	Critical	Yes	Yes
	Final Examinations & Grade Approval	Critical	Yes	TBD
	Remote Teaching and Distance Learning	Critical	Yes	Yes
	Independent Study Admin & Oversight	Enhancing	Yes	No
	Summer Internships / Development Experiences	Enhancing	Yes	TBD
	Course-level Field Trips	Enhancing	Yes	Yes
	Guest Lectures	Enhancing	Yes	Yes
Lab & Research	Lab Tech Support to Classes	Critical	Yes	Yes
	Lab Tech Support to Faculty Research	Critical	Yes	TBD
	Lab Equipment Operations & Maintenance	Critical	Yes	No
	Senior Faculty Research Programs	Essential	Yes	TBD
	Lab Space Allocation Procedures	Essential	Yes	Yes
	Lab Supply Ordering & Maintenance	Essential	Yes	TBD
	Lab Resource Committee & Budget Management	Essential	Yes	No
	Lab Information Technology Management (& 3D Printer)	Essential	Yes	No
	Junior Faculty Research Involvement	Enhancing	Yes	TBD
	Projects Day Coordination	Enhancing	Yes	TBD
Communication	Knowledge Management / SharePoint Maintenance	Essential	Yes	Yes
	Program Website	Enhancing	No	N/A
	External Advertising	Enhancing	Yes	No

Table 2. Identified major activities. Continued.

Category	Activity	Classification	Impacted by COVID-19?	Opportunity to Bounce Forward?
Faculty Development	Counseling Program (Formal, Informal)	Critical	Yes	TBD
	Faculty Selection	Critical	Yes	Yes
	New Faculty Onboarding Program	Critical	Yes	TBD
	Classroom Observation & Feedback	Essential	Yes	Yes
	Academic Promotion Preparation	Essential	Yes	No (Delayed)
	Certification Prep – Professional Engineer License	Essential	No	N/A
	Graduate School Mentorship	Essential	No	N/A
	Certification Prep – Military Intermediate Level Ed.	Enhancing	No	N/A
	Faculty Seminars	Enhancing	Yes	TBD
	Support to Master Teacher Program	Enhancing	No	N/A
	Arriving Faculty Sponsorship Program	Enhancing	No	N/A
	Certification Prep – Project Management Professional	Ancillary	Yes	TBD
Student Development & Services	Student Academic Counseling	Critical	Yes	TBD
	Student Recruiting into Environmental Engineering Major	Critical	Yes	TBD
	Fundamentals of Engineer Exam Prep & Coordination	Enhancing	Yes	TBD
	Semester Abroad Program Coordination	Enhancing	Yes	TBD (Cancelled)
	Environmental Club – Leadership & Admin Oversight	Enhancing	Yes	TBD
	Environmental Club – Student Welcome Event	Enhancing	Yes	Yes
	Environmental Club – Annual Service Activities	Enhancing	Yes	TBD (Cancelled)
	Program-level Graduation Event	Enhancing	Yes	TBD
	Open House	Ancillary	Yes	Yes
	Graduation Video	Ancillary	Yes	TBD (Cancelled)
	Senior Boat Ride	Ancillary	Yes	TBD (Cancelled)
	Environmental Club – Beer Tasting Event	Ancillary	Yes	TBD (Cancelled)
	Order of the Engineer Ceremony	Ancillary	Yes	TBD
	Summer Leader Experience Support	Ancillary	Yes	TBD (Cancelled)

[1] An additional six activities were binned into a “Leader and Service Responsibilities” bin but are not listed above for brevity and the fact the position itself did not change due to COVID-19.

the ‘Teaching’ category had the highest number of ‘critical’ activities (5 critical of 9 total activities identified). This result is in-line with West Point’s mission and vision, which centers on education and student development rather than research.

Activities in the ‘Lab & Research’ category do, however, play an integral role in our program’s educational process. As shown, 8 of the 10 activities (80%) identified in this category were considered ‘critical’ or ‘essential’. We identified a similarly high percentage of activities in the ‘Assessment & Accreditation’ category as ‘critical’ or ‘essential’ (5 of 6, 83%). Conversely, despite having the highest number of activities (14), we identified only two ‘critical’ activities in the ‘Student Development & Services’ category. Most ‘critical’ or ‘essential’ student services are not conducted at the program-level, but instead at a department-level and/or the Dean directorate-level. Student development and service activities at the program-level, on the other hand, are primarily designed to enhance the student experience.

Further, of the 60 identified activities, we determined that 46 activities (77%) were directly impacted by COVID-19 in some way, while only 14 activities were not (Table 2, Column 4). We binned the 14 activities not impacted by COVID-19 in one of two ways. First, 8 activities were conducted via remote or digital means before COVID-19 and our program was able to seamlessly execute each despite the pandemic. While we may be able to adjust some of these activities in the future, we elected to bin each as ‘N/A’ when assessing ‘bounce forward’ opportunities (Table 2, Column 5). Second, we elected not to identify the six ‘Leader and Service Responsibilities’ as ‘Impacted by COVID-19’. While each leader was forced to deal with the impacts of COVID-19, we suggest that the fundamental responsibilities of the leader position did not change.[1]

Of the 46 activities directly impacted by COVID-19, we assessed each and binned them in one of three ways: (1) ‘yes’ an immediately opportunity to ‘bounce forward’ exists, (2) ‘TBD’, i.e., we are still assessing the impact of COVID-19 on the activity, or (3) ‘no’ immediate opportunity to ‘bounce forward’ exists. Using these criteria, we determined that 15 activities provided an immediate ‘bounce forward’ opportunity (i.e., were ‘yes’), 24 activities needed more assessment (i.e., were ‘TBD’), and only 6 activities provided no immediate opportunity to ‘bounce forward’ (Table 2, Column 5). Of these 6 activities, one was ABET reaccreditation, which our program executed remotely during the pandemic, one was independent study administration, and three were lab-related practices that we do not foresee changing near term.

Most immediate opportunities to ‘bounce forward’ in our program (i.e., activities with ‘yes’ in Table 2, Column 5) involve the integration of digital technologies. The Office365 suite, to include Microsoft Teams, and the expanded use of cloud-based information sharing has allowed our program to streamline operations and expand remote work options. Not only had our program transitioned to remote teaching, but we also moved many labs to become remote learning experiences, selected new faculty through a series of virtual interviews and teaching activities, conducted our ABET Board of Advisors annual meeting virtually, and conducted our open house

[1] Activities in the ‘Leader and Service Responsibilities’ bin were undoubtably impacted by ‘COVID-19’ and there may be opportunities to ‘bounce forward’; however, we argue that leader positions by their very nature should be flexible and adaptable to changing conditions. Further, opportunities to ‘bounce forward’ in this area are likely to be specific to individuals and unique to organizations; therefore, we elected not to explore leader activities in this analysis.

for new students virtually. We will keep many of these changes beyond the pandemic. Sections 6.3 and 6.4 highlight in more detail some of the ways our program has integrated remote teaching and learning practices during the pandemic.

Despite immediate opportunities to 'bounce forward' using digital technologies, many more activities (n = 24) still need more assessment prior to determining if our program will make long-term changes post-pandemic. Considering the resilience model presented in Figure 1, the large number of 'TBD' activities strongly indicates that we are still in 'Recovery' (Step 3) and that there are substantial opportunities for continued assessment and improvement as we 'Adapt' and become more resilient long-term (Step 4). Sections 6.5 and 6.6 explore two areas in which our program may be able to 'bounce forward' but more analysis is required over time to fully realize the opportunities.

6.3. Immediate 'Bounce Forward': Integrating of Remote Teaching and Learning Practices

While the integration of digital technologies has facilitated 'bounce forward' opportunities in several areas, perhaps the most important in meeting our program's vision is the integration of remote teaching and learning practices. At the onset of the COVID-19 pandemic in March 2020, West Point pivoted from face-to-face instruction to remote teaching within one week. West Point asked faculty to be inclusive, flexible (especially with student connectivity), and compassionate with challenges associated with remote education. Simultaneously, West Point asked programs to hold students to the same standard of quality work we expect with face-to-face instruction, as well as attainment of previously published learning objectives.

To meet these challenges, faculty in our program employed a variety of remote teaching approaches to facilitate student learning. Many faculty members in our program flipped their classrooms to enable students to study lecture material prior to class. With the flipped classroom approach, faculty also integrated new methods to keep students engaged. One approach was to create pre-recorded slideshows where students could review course material at their leisure prior to or after class. Some faculty also recorded synchronous remote classes and posted them on-line afterwards for student review.

Faculty in our program primarily used Microsoft Teams and the Virtual Classroom option in BlackBoard Collaborate to hold remote classes. In these platforms, many instructors used breakout groups so that student teams could work through challenging concepts and/or additional problems not included in the pre-recorded material. After each group spent time discussing concepts or problems, the class would come back together to complete coverage of the material. In addition to functions organic to Teams or BlackBoard, some instructors employed Google Jamboard, which allowed all students to show their work to the instructor.

Beyond the classroom, labs were also transitioned to remote, asynchronous events. For each, students were required to watch pre-recorded videos of the instructor and lab tech completing the lab; however, student engagement was required throughout. Specifically, students collected data from the recordings for subsequent analysis and group work. We also transitioned field trips to our local water treatment and wastewater treatment plants to virtual experiences. One

instructor videoed both field trips and wrote assignments asking the students to answer questions on concepts introduced during the recordings.

Additionally, our program elected to modify the format and administration of many course final exams. Traditionally, our university allocates 3.5-hours for face-to-face final exams; however, many final exams were modified to become open-ended events executed remotely over a seven-day timeframe. Students could use reference material, to include textbooks and notes, to help synthesize information and demonstrate understanding of course-level objectives. While still an area of discussion, our program is likely to maintain the open-ended remotely executed final examination format for several of our courses.

Faculty within our program have continued to develop and refine remote learning approaches through the publication of this study. As we continue to wrestle with the challenges of COVID-19, to include frequent student quarantines, we have taken effort to deliver classes to students attending both in-person and remotely. To date, student feedback regarding remote teaching approaches has been mixed. While some positive attributes are evident, such as the ability to conduct remote teaching to students not physically located at West Point, more assessment data is needed over time to determine the efficacy of remote learning approaches we have implemented. Further, while administering courses in blended synchronous or hybrid flexible (HyFlex) formats has anecdotally proved taxing on instructors, it may yield many 'bounce forward' opportunities as we continue to reflect in the near future.

6.4. Immediate Bounce Forward: Environmental Engineering Technologies Course-level HyFlex Example

While the pandemic forced many courses to be taught remotely, it has also provided opportunity for faculty to experiment with different teaching modalities, such as blended synchronous or HyFlex (Glantz and Gamrat, 2020). West Point requires all graduates, regardless of academic major, to complete a series of math, science, and engineering courses. One requirement for non-STEM majors is to complete a three-course sequence of engineering courses in infrastructure, cyber, robotics, environmental, nuclear, or systems engineering. Our program administers the Environmental Engineering 3-Course Sequence (EES), which consists of EV300 (Environmental Science), EV350 (Environmental Engineering Technologies), and EV450 (Environmental Engineering for Community Development) (Wallen et al. 2020).

An example of an immediate 'bounce forward' was the transition of our middle EES course, EV350, to a HyFlex format for the Spring 2021 offering. EV350 is offered to approximately 200 junior- and senior-level students each year. Each class includes approximately 16 students, which are distributed between multiple instructors. At present, EV350 offers 38 virtual lessons, 2 virtual labs, and 2 virtual field trips. Prior to each lesson, students asynchronously attend virtual class by viewing a pre-recorded PowerPoint presentation, each between 30 and 60 minutes in length, at their own pace. During the synchronous in-class time, students can ask questions, work on in-class problems, and attend break-out groups to work on upcoming assignments. Students can elect to attend in-class synchronous activities in-person or on-line, providing them maximum flexibility. This approach also provides an inclusive environment for students who are in quarantine. Students are incentivized to complete both synchronous and asynchronous

events using instructor points (i.e., each event equates to a set number of instructor points). This approach allows instructors to monitor asynchronous activities while encouraging the students to engage with the material at their own pace. A more complete description of the course, to include explanation of specific synchronous and asynchronous events in EV350, is found in Linvill et al. (2021).

6.5. Eliminating Unnecessary Activities – 'Do Less, Better'

In classifying all program-level activities as 'critical', 'essential', 'enhancing', or 'ancillary', we can review our program comprehensively and identify relatively low-return endeavors. By eliminating or reducing low-return endeavors in the program, we can make available more of what restricts our ability to improve our resilience baseline under routine conditions: time. While many activities remained during the pandemic, most institutions were forced in some sense to 'clear the plate' of all but the most critical and essential tasks required to maintain system functionality. Tasks that were removed, many of which were classified as enhancing or ancillary, can be reviewed prior to adding them 'back to the plate'. Now is an opportune time to design measures to assess the extent to which activities like field trips, club activities, and guest lectures contribute to program objectives. Some guest lectures, for example, might be more easily conducted remotely in a post-COVID-19 era. While time previously devoted to arranging travel, logistics, and escorting could be applied to higher priority, transformational initiatives.

As seen in Table 2, many student activities classified as 'ancillary' were cancelled (n = 6) in 2020 and early 2021. Some of these activities have been tentatively scheduled for future dates, while others have not. The future execution of some 'ancillary' student events is still 'TBD' and some may be permanently cancelled. For example, our program normally puts together a lengthy graduation video for students. While appreciated, the video can likely be reduced or eliminated to save faculty time with minimal or no impact to students. Despite projected benefits, eliminating activities post-pandemic may, however, have unintended long-term impacts. For example, fewer students may sign-up for the major if our program is perceived to provide an impersonal experience. Student feedback during this process remains important to ensure our program continues to address student needs. To this end, we collect formal student feedback at the end of each semester. Much of the feedback provided will be used to continually assess changes we have made during the pandemic.

While targeting 'ancillary' and 'enhancing' activities for possible elimination may seem easiest, we recommend that programs take the opportunity to assess *all* activities. Examining 'critical' and 'essential' activities can lead to smarter (i.e., more efficient or effective) ways of completing those activities. Further, programs may identify ways of synergizing or merging 'critical' or 'essential' activities to 'bounce forward'. For example, our program is exploring ways to digitize annual course assessments to improve course management practices and capture continuous course-level improvements for future ABET reaccreditation.

6.6. Re-evaluating Lab Conduct, Organization, Space, and Equipment Requirements

Another area in which we can possibly 'bounce forward' after further reflection and assessment is lab-related practices, to include lab conduct, organization, and equipment used. Beyond

EV350, our program made recordings of class laboratory experiments in *all* our classes because students were unable to execute labs face-to-face during the pandemic. Like EV350, many of the videos required students to collect data from the recording, thereby keeping them engaged. Creation of these videos will likely benefit our program over the long term as well. For example, these recordings will serve as a back-up when students are unable to attend labs face-to-face. Further, students can review the labs in video format while preparing laboratory reports. Hybrid synchronous, asynchronous labs are also an option which we will explore further. For example, we recently asked students in our Physical and Chemical Treatment course to watch a video of a complicated module of a reactor lab (CSTRs in series) and complete remaining portions of the lab face-to-face.

The transition to remote teaching during the COVID-19 pandemic required that we change or drop numerous lab assessment instruments and student experiences during the spring semester in 2020. Henceforth, we are reevaluating the cost/benefit of selected laboratories, to include space and equipment requirements. For example, our EV350 course includes a wastewater analysis lab, for which we have employed both chemical oxygen demand (COD) and 5-day biological oxygen demand (BOD_5) to demonstrate organic removal in past years. Moving forward, we are exploring a hybrid of asynchronous videos and synchronous lab experiences that will reduce the overall lab bench space required, as well as reduce the number of BOD incubators needed. Such a change could open space for other independent research endeavors, or to expand labs in other courses.

7. Way Ahead: 'Bouncing Forward' Over the Next 3-5 Years

Figure 2, Step 6 states that programs should "Take steps to make the change 'permanent'. Look for synergies between activities. Create a timeline for action". The large number of activities with 'bounce forward' opportunities classified as 'TBD' in Table 2 suggests that our program needs to conduct more self-reflection and assessment, likely over the next 3-5 years (or more). Indeed, 'bouncing forward' is an on-going process. It is likely that further assessment and evaluation will result in additional changes across the spectrum of activities in the program for the foreseeable future. To measure and quantify 'resilience' in the coming years, our program intends to undertake several measures. First, program leadership will participate in a Department-level effort to identify and implement 'bounce forward' opportunities. Continual dialogue both within our program and other peer programs regarding resilience will be a critical component of our efforts. Second, our program intends to conduct continual and iterative assessments of our activities considering resilience principles. This study is not a 'one and done' but is an on-going effort over time. Third, our program leadership intends to conduct faculty seminars and off-sites centered on 'bounce forward' topics, continuous assessment, and improvement. Finally, we intend to leverage our ABET Board of Advisors to provide external feedback concerning our 'bounce forward' efforts.

It is important to note that 'bouncing forward' will look different for each organization; however, we propose three general principles: analyze *each* activity deliberately, avoid silos, and embrace change. First, prior to adding any activity back to 'the plate', *all* activities should be examined critically. No activity should be considered untouchable. If the cost of the activity in terms of money, faculty time, and student time does not outweigh the developmental benefit,

then the activity should be modified, reduced, or eliminated. Second, ‘bouncing forward’ defies traditional boundaries. We recommend responses to the pandemic cross programs and departments. Disruptive events do not respect borders or administrative silos (Hynes et al. 2020), and a ‘bounce forward’ response from COVID-19 should similarly emphasize collaboration across boundaries. Finally, we recommend orienting on transformational change. Our environment has fundamentally shifted due to the COVID-19 pandemic. While many of our activities, systems, and processes could return to “normal” (i.e., the pre-pandemic baseline), such an outcome squanders the opportunity to reimagine the way we do business.

8. Conclusion

Our hope is that this paper stimulates thought, conversation, and ultimately action. ‘Bouncing forward’ will look different for each organization and individual. However, taking a step-back now gives the opportunity to examine long-standing practices and ask, “is this the way we should be doing business?”. Most institutions are still recovering (Figure 1, Step 3) from the COVID-19 pandemic. We recommend that institutions take measures, using the approach outlined in this study, to 'bounce forward’ and educate students from a position of renewed strength and resilience in an uncertain, post-pandemic future.

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References

Aguilera-Hermida, A. P. (2020). College students’ use and acceptance of emergency online learning due to Covid-19. *International Journal of Educational Research Open*, *1*, 100011. https://doi.org/10.1016/j.ijedro.2020.100011

Anstey, M. R., Blauch, D. N., Carroll, F. A., Gorensek-Benitez, A. H., Hauser, C. D., Key, H. M., Snyder, N. L. (2020). # DavidsonTrue: Transitioning to Remote Teaching while Maintaining Our Values as a Liberal Arts College during the COVID-19 Pandemic. *Journal of Chemical Education*, *97*(9), 2800-2805. https://dx.doi.org/10.1021/acs.jchemed.0c00782

Baran, E., & Alzoubi, D. (2020). Human-centered design as a frame for transition to remote teaching during the COVID-19 pandemic. *Journal of Technology and Teacher Education*, *28*(2), 365-372.

Cucinotta D, Vanelli M. (2020). WHO Declares COVID-19 a Pandemic. *Acta Biomed*. 2020 Mar 19;91(1):157-160. doi: 10.23750/abm.v91i1.9397.

Daniel, J. (2020). Education and the COVID-19 pandemic. *Prospects*, *49*(1), 91-96. https://doi.org/10.1007/s11125-020-09464-3

Eisenberg, D. A., Linkov, I., Park, J., Bates, M., Fox-Lent, C., & Seager, T. (2014). Resilience metrics: lessons from military doctrines. *Solutions*, *5*(5), 76-87.

Gillis, A., & Krull, L. M. (2020). COVID-19 Remote Learning Transition in Spring 2020: Class Structures, Student Perceptions, and Inequality in College Courses. *Teaching Sociology*, *48*(4), 283-299. https://doi.org/10.1177/0092055X20954263

Glantz, E. J., & Gamrat, C. (2020). The new post-pandemic normal of college traditions. In *Proceedings of the 21st annual conference on information technology education*, October 2020, pp. 279-284.

Hynes, W., Trump, B., Love, P., & Linkov, I. (2020). Bouncing forward: a resilience approach to dealing with COVID-19 and future system shocks. *Environment Systems and Decisions*, 40: 174-184. https://doi.org/10.1007/s10669-020-09776-x

Lederman, D., How Teaching Changed in the (Forced) Shift to Remote Learning. *Chronicle of Higher Education*, 22 April 2020. https://www.insidehighered.com/digital-learning/article/2020/04/22/how-professors-changed-their-teaching-springs-shift-remote (accessed 15 December 2020).

Linkov, I., Eisenberg, D. A., Bates, M. E., Chang, D., Convertino, M., Allen, J. H., & Seager, T. P. (2013). Measurable resilience for actionable policy. *Environmental Science & Technology,* 47, 10108-10110. dx.doi.org/10.1021/es403443n

Linkov, I., Bridges, T., Creutzig, F., Decker, J., Fox-Lent, C., Kröger, W., & Thiel-Clemen, T. (2014). Changing the resilience paradigm. *Nature Climate Change*, *4*(6), 407-409.

Linvill, C., Wallen, B., Pfluger, A., Butkus, M. (2021). Incorporation of Best Practices in Environmental Education to Maximize Student Engagement and Instructor Efficiency. 2021 ASEE St. Lawrence Section Annual Conference. DOI pending.

National Research Council 2012. *Disaster Resilience: A National Imperative*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13457

Ortiz, P. A. (2020). Teaching in the time of COVID-19. *Biochemistry and molecular biology education*. 2020:1. DOI: 10.1002/bmb.21348

Sikula, N.R., Mancillas, J.W., Linkov, I., & McDonagh, J.A., (2015). Risk management is not enough: a conceptual model for resilience and adaptation-based vulnerability assessments. *Environment Systems and Decisions*, 35: 219-228. DOI 10.1007/s10669-015-9552-7

Wallen, B. M., & Butkus, M. A., & Sheehan, N. P., & Ng, A., & Pfluger, A. R., (2020). Engaging Students Through an Interactive Mass Balance Fundamentals Demonstration. Paper presented at 2020 ASEE Virtual Annual Conference Content Access. DOI: https://doi.org/10.18260/1-2--34542

Wied, M., Oehmen, J., Welo, T. (2020). Conceptualizing resilience in engineering systems: An analysis of the literature. *System Engineering*, 23: 3-13. DOI: 10.1002/sys.21491