# COVID-19 Impact on Fabrication and Design in APL's Concept Design and Realization Branch

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## ABSTRACT

*The COVID-19 pandemic upended normalcy around the world, particularly in the workplace. At the Johns Hopkins University Applied Physics Laboratory (APL), staff members in the Concept Design and Realization Branch had to adjust their work practices to prevent disease outbreaks while continuing to design and fabricate critical components for diverse missions. In addition to adhering to Labwide safety measures such as social distancing and cleaning protocols, the design and fabrication teams modified their workstations and processes; adjusted work schedules; adhered to expanded cleaning protocols; and leveraged digital communication and collaboration tools to ensure continuity of operations. As the pandemic has waned, some of these measures have been phased out. However, some of these tools and practices have proven to be highly valuable under normal operations and have become part of the new normal. Using these tools and methods, the design and fabrication teams successfully delivered major projects over the course of the pandemic, demonstrating resourcefulness, adaptability, and commitment in the face of difficulty.*

## INTRODUCTION

As APL continues to navigate to normal as the COVID-19 pandemic wanes, it is worth reflecting on the pandemic's impact on the product realization process and how that impact might shape our future. When COVID-19 first arrived in March 2020, fabrication staff members in APL's Concept Design and Realization Branch, like people all over the world, had many questions: Can COVID be transmitted by touching surfaces? How closely can individuals safely interact and for how long? Are masks effective? What are the symptoms? How afraid should we be? Many APL staff members were fortunate to be able to work either somewhat or entirely remotely, reducing the fear of contracting or spreading COVID-19 in the workplace. But others, such as those who fabricate, assemble, and handle hardware, could not take home sensitive electronics or a 22,000-lb. five-axis mill, so they had to continue to work on-site. Similarly, design teams had grown accustomed to communicating many details via visual in-person discussions because of the risk that they could be misinterpreted when shared remotely. Despite the pandemic and the questions and challenges it brought, APL's Concept Design and

Realization Branch continued to contribute to the Lab's critical programs. This article explores how the teams in the branch embraced the Lab's core values and adapted in real time to the pandemic, and how these adaptations may help to facilitate future innovation.

## BUSINESS, BUT NOT AS USUAL

Unquestionable integrity, trusted service to the nation, world-class expertise, game-changing impact, and a highly collaborative, fulfilling (even fun!) environment—these are the core values that motivate APL every day. In addition, the Lab developed six precepts to guide policies and practices during the pandemic: safety, mission, flexibility, viability, strategy, and compassion. APL's commitment to its staff and its mission guided its strategy and policies to keep staff members safe while they continued to have game-changing impact for the nation. The Lab's culture of innovation helped staff members embrace new workplace realities with flexibility and compassion. While many organizations shuttered their doors temporarily, some for extended times, APL remained open for business, albeit with some adjustments.

From the outset of the pandemic, APL's Environmental Health and Safety (EHS) team recognized the fundamental need to protect the staff. Some protective measures were common across the Lab—for example, APL required staff members to report all cases and to maintain close contact logs to enable complete contact tracing, to adhere to consistent quarantine requirements and return-to-work procedures, and to limit the number of people in certain shared areas such as conference rooms.

Housekeeping staff members dealt with the new realities of the pandemic as closely as anyone at the Lab, and they were vital to keeping operations moving. In the early stages of the pandemic, before much was known about the likelihood of spread through surface contamination, APL's housekeeping and EHS teams coordinated efforts to clean areas more frequently and to notify staff members when areas were cleaned so that they felt safe working in the areas. They also quickly identified necessities like hand sanitizer, monitored potential supply shortages, and worked with vendors to ensure that sufficient quantities of cleaning and personal supplies were available.

Although COVID-19 transmission factors were not completely understood at first, two considerations were generally assumed to be important: filtering the air and bringing as much outside air as possible into buildings. APL's Business, Construction, and Facilities Department (BCFD) had been proactively working to improve filtration even before the onset of COVID-19, putting the Lab in a great position when airborne exposure was identified as the predominant method of COVID-19 transmission. Fortunately, many air handling systems in APL's buildings already included filters with a minimum efficiency value (MERV) of 13, which can capture virus particles to prevent recirculation. Where possible, filters were changed or replaced with MERV 14 filters to further improve the filtration rate. In air handling equipment that was not designed to operate with the air flow resistance caused by a MERV 13 filter, ultraviolet light was deployed inside the ductwork (using a 360° high-output commercial UV-C lamp that outputs >420 $\mu W/cm^2$ at 1 m, up to two times the ultraviolet irradiation levels required to disinfect coils). Finally, outside make-up air was maximized.

Communication was also a key component of the Lab's approach. Staff members were regularly informed of policies and procedures, especially as they were updated. Detailed, regular communications were developed by the chief of staff, the Communications Department, and EHS. Signage was installed around the campus to communicate policies for wearing masks, monitoring symptoms, and limiting the number people allowed in a space. In addition, a new internal website served as a central repository for information on COVID-19 policies and statistics. While maintaining appropriate privacy controls, the site informed staff members about case rates and quarantines involving APL staff members.

But a challenge arose when considering the wide range of work performed at APL, including engineering, lab work, mechanical and electrical manufacturing, and work in secure spaces. These disparate work environments meant that a single set of rules would not suffice. Instead, each group would need to tailor its response to ensure both the safe interactions of its staff and the continuation of its core functions.

## A TAILORED APPROACH

This section describes examples of how the mechanical fabrication, electrical fabrication, and engineering design teams adapted in various, often creative, ways to maximize safety while ensuring that their work continued uninterrupted.

### Mechanical Fabrication

The mechanical fabrication area includes machining, sheet metal fabrication, welding, additive manufacturing, and composites work. While staff members supporting certain fabrication tasks, such as planning, could work remotely, others could not. The approximately 50 individual staff members who continued working on-site quickly adapted to a new set of norms to ensure that work continued safely. Schedules were staggered as much as possible to reduce the probability of close contact. In the machine shop, individuals spend most of their time at workstations designed for a single person, and because

the machines are so large, social distancing measures were simple to implement in theory. In practice, they were complicated by the need to hand off hardware and paperwork and share common equipment such as calibrated inspection tools. But the biggest difficulty in implementing social distancing stemmed from the fact that staff members share machining practices with their coworkers to ensure consistent production of high-quality, complex hardware, and doing so sometimes requires close proximity. It was impossible to maintain 100% social distancing, as staff members frequently needed to work closely to accomplish their jobs.


**Figure 1.** APL's electronics assembly lab. Staff members are masked and socially distanced to ensure their safety while working during the pandemic.

Before the pandemic, staff members in the machine shop worked in two shifts, a day shift and an evening shift (with the transition occurring at 3:30 p.m.). As shifts changed, staff members met face-to-face and verbally shared information and objectives. To achieve social distancing, this exchange transitioned from a face-to-face meeting to sharing information using large monitors that could be seen from an appropriate distance, along with written documentation of most key points. This process has proven valuable even as the pandemic wanes.

Material handling is another area that required adjusted procedures. Throughout the fabrication process, material is handled by a number of individuals performing different steps. During COVID, these handoffs also needed to be consistent with other safety measures—notably, cleaning the material between staff members handling it. While the additional handling requirements were not necessarily difficult to implement, they provide yet another example of an adaptation to ensure safety.

## Electrical Fabrication

At the beginning of the pandemic, the electrical fabrication group (Figure 1) coordinated with the mechanical fabrication group and arrived at a similar strategy to continue working while ensuring safety. Before the pandemic, electrical fabrication staff members worked only one shift (a daytime shift). During COVID, they began working 10 hours a day for 4 days a week on a staggered schedule, Monday through Thursday or Tuesday through Friday. This adjusted schedule meant that less staff members were in the facility on Mondays and Fridays, which helped reduce exposure if staff members started feeling ill over the weekend. In addition, labs and workstations were moved to ensure a minimum separation of 6 feet while still ensuring access to an electrostatic discharge safe floor.

Other logistical changes included assigning lab coats to each engineer instead of sharing them, marking labs' entry and exit paths to reduce close contact among staff members coming and going, and setting up and using storage lockers in the main hallway to limit the number

**Figure 2.** Personal safety equipment. Procuring and utilizing proper safety equipment was critical to the continued operational success of the fabrication and design teams in APL's Concept Design and Realization Branch. Left, lab coats were assigned to each engineer instead of being shared, and storage lockers were set up in the main hallway to limit the number of technicians using shared breakrooms. Right, many electrical fabrication tasks require staff members to wear gloves to protect the components they are working with, and during the pandemic, the Lab enacted various measures to address supply challenges.

of technicians using shared breakrooms (Figure 2). Manufacturing engineers and other staff members who had routinely worked outside the assembly labs spread out into office space no longer being used by colleagues who were working from home.

Many electrical fabrication tasks require staff members to wear gloves to protect the components they are working with (Figure 2), particularly those working on components that must meet planetary protection requirements. During the early stages of the pandemic, glove supplies were challenged by the uncertainty associated with spread of SARS-CoV-2 via surface contamination. To ensure sufficient supply during shortages, the Lab worked with multiple vendors and made strategic decisions about how to best allocate its supply of gloves. For example, more expensive robust gloves were used for fabrication work, while less expensive gloves were used for quick work, including part handling and moving.

Assignment protocols were also updated. Because of the complexity of hardware built at APL and the close collaboration required with engineering teams, before COVID, the preferred process was to assign a single technician to each assembly package. The pandemic environment forced a change to this practice, requiring that multiple technicians be assigned to each build to prevent a single point of failure should anyone need to quarantine on short notice. Because of the resultant cross-training and knowledge capture, this protocol is still frequently practiced as the Lab moves toward standard operations.

With social distancing practices and many staff members outside of electrical fabrication working remotely, face-to-face meetings were no longer feasible during the pandemic. When fabricators needed clarification from others, such as program engineers, they took full advantage of video teleconferencing software and other digital tools to communicate. These practices ensured continued progress on parts, but perhaps more importantly, they demonstrated the lasting value of using digital collaboration tools to maximize efficiency, and these tools are now regularly used during working arrangements even as the pandemic wanes.

## Engineering Design

Much of the critical detailed design work is done by an individual working alone on a computer, so unlike fabrication, engineering design could be done remotely. But the real question was whether it could be done *effectively* and *efficiently* from remote locations. The design process includes many micro-collaborations, where individuals drop in and ask a quick question of a colleague who has had a similar design problem. These collaborations allow design groups to replicate lessons learned and best practices across groups. Of course, this sort of collaboration is much harder to do remotely.

Engineering design staff members rose to the challenge, using online group discussion tools to pose general questions and holding virtual ad hoc design reviews. One collaboration tool that engineering designers leveraged was an online whiteboard platform (Figure 3) that had been unfamiliar to many of them before March 2020. This tool allows many people to collaborate simultaneously by updating a shared virtual space with ideas, comments, and questions. One specific benefit that this web-based tool has over traditional brainstorming is simultaneous idea sharing, as opposed to each individual speaking in turn during a traditional in-person session.

As APL continues to navigate to its post-COVID work environment, these tools are increasingly used in virtual, in-person, and hybrid settings. Although it can be argued that nothing can replace in-person collaboration, many of the digital tools used during the pandemic can enhance even the in-person experience as part of the new normal.

## SUCCESS STORIES

Despite all these measures, difficulties inevitably arose. Unfortunately, some staff members did get sick, and more had to quarantine. Some external fabrication facilities that APL routinely collaborates with closed at

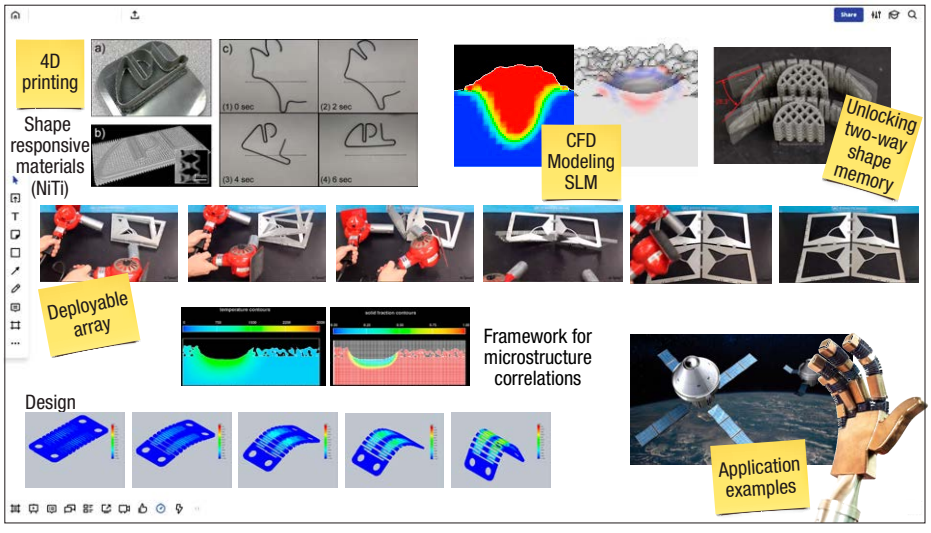


**Figure 3.** An example digital white board. The engineering design team used a web-based tool to collaborate remotely, particularly for brainstorming. The example shown is a board for 4-D printing.

the onset of the pandemic, so additional critical work transitioned to the APL fabrication staff. These challenges were overcome thanks to the competence and conscientiousness of individual staff members. As important as the Labwide changes were, it was each individual's commitment to represent APL's core values that allowed the fabrication teams to succeed during the pandemic.

An example of all these stories coming together into a single success is the DART (Double Asteroid Redirection Test) spacecraft. DART was the first-ever space mission to attempt to demonstrate asteroid deflection by kinetic impactor: the aim of the mission was to test this method of defending Earth against asteroids and other near-Earth objects by crashing the spacecraft into a double asteroid in an attempt to alter its course. Despite a challenging schedule and a few inevitable setbacks during fabrication, assembly, and testing, DART launched successfully on November 24, 2021, after much of its fabrication had occurred at APL during the pandemic. In addition to working with the process modifications previously described, the DART engineers adapted their workflow even further to ensure mission success.

For example, circuit boards ordinarily pass between assembly and test engineering technicians frequently, but because assemblies were being left in isolation for a few days to minimize contact contamination during the pandemic, the DART team streamlined this process to reduce the number of transitions. To minimize the chance of quarantine impacting the schedule, key staff members were isolated from each other to the maximum extent possible. Instructions were provided in writing or communicated via online tools, and probing and debugging also occurred virtually. Despite these challenges and changes, the DART spacecraft was delivered on time and launched successfully—a culmination of incredible work by adaptable and dedicated staff members.

A novel personal protection system is another example of successful (and resourceful) engineering design and fabrication accomplished despite the pandemic. For this project, all collaboration on requirements derivation, design options, fabrication, and testing occurred virtually. In addition, all fabrication and assembly efforts were carried out in individual staff members' garages and basements, using parts bought online and delivered to their locations and with tools either personally owned or borrowed from APL.

## LEARN TO GROW, GROW TO LEARN

It goes without saying that the COVID-19 pandemic had a devastating impact on people worldwide, and APL staff members were no exception to that. At the same time, however, it catalyzed and accelerated an evolution in the workplace, especially for organizations with a sprawling and varied campus like APL. For APL, the timing of COVID fortuitously aligned with the planned move of the Concept Design and Realization Branch engineering design teams to a new building on campus (Figure 4). Change that may have taken years under normal circumstances happened in months after the start of the pandemic, presenting immediate opportunities to find creative ways to interface and collaborate within and across teams whose members are working in various locations.

While it can be argued that nothing will ever replace face-to-face collaboration as a key to innovation, during the pandemic, APL engineering design and fabrication teams demonstrated that many routine tasks can be done quite effectively by virtual means. Technology allows for more virtual meeting and brainstorming options, and staff members have had the time to learn and incorporate these tools into their new routines. In fact, as APL started to rely more on video teleconferencing software, it became apparent that the technology


**Figure 4.** Building 201. REDD designers, engineers, and many others relocated to the newly constructed Building 201 on the south side of the APL campus during the spring of 2021. Change that may have taken years under normal circumstances happened in months after the start of the pandemic, giving staff members immediate opportunities to find creative ways to interface and collaborate within and across dispersed teams. (Photo courtesy of CannonDesign.)

offers some advantages for the future workplace beyond the pandemic. For example, the ability to share designs on screen, annotate them in a live environment, and capture and share the results electronically has replaced crude conference room whiteboard sketches and handwritten notes. Also, gathering people into a common virtual space can sometimes happen more quickly than gathering in a common physical space. And existing calendar tools, like that in Outlook, can be used to share work hours and locations.

As APL continues to grow, incorporate more remote staff, and navigate to post-pandemic times, embracing these technologies is more important than ever. The pandemic has taught us that we can adapt to a less centralized environment and combine the spark of in-person collaboration with the efficiency of virtual meetings.

## CONCLUSION

When COVID-19 emerged as a significant worldwide concern in the spring of 2020, how individual organizations would react was not immediately clear. What was clear, however, was that APL engineering design and fabrication teams had important missions to continue. The teams moved forward together by implementing changes to protect individual health and continue their critical contributions. Some of these tools and processes have proven valuable even as the pandemic wanes. As APL continues to navigate toward normal, it also continues to realize products effectively even when staff members are not located in the same physical spaces. The adaptability and resourcefulness of APL's staff members, combined with their commitment to the Lab's core values, will ensure that no matter what the post-pandemic workplace looks like, APL will continue to evolve its robust product realization processes to make critical contributions to critical challenges.

**ACKNOWLEDGMENTS:** It is important to acknowledge that staff members who continued to work on APL's campus during the pandemic experienced heightened levels of anxiety or concern. Regrettably, some people did become ill with COVID-19. These individuals made both mental and physical sacrifices to ensure that the Lab's critical missions remained on track. Their sacrifices do not go unrecognized, and we thank them for their effort and service.

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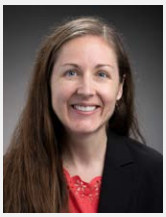

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