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# Processes and Best Practices from the US Navy Vaccination Center at Bloch Arena

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**Abstract**

The U.S. Navy vaccination center at the Bloch Arena on Joint Base Pearl Harbor-Hickam was observed and analyzed for processes and flow rates. We estimate that the current single shift of 60 staff working medical and administrative processes can administer up to 2,500 vaccinations each day. Increased demand will require a second shift. We document best practices, including facility choice, a well-constructed flow pattern, queue-formation engineering, staff task specialization, personnel cross-training, overstaffing nodes, and constant improvement and innovation Our only current substantive recommendation is to implement a work-day maximum for the staff, similar to aviators' flight-day, to guard against burn-out and fatigue-related errors.



This work was performed under Federal Government Contract No. N00014-16-D-5003.

**Cover image credit**: "Liquid gold" Pfizer-BioNTech COVID-19 vaccine vials at the Bloch Arena vaccination Center. Image courtesy of CAPT Jaime Quejada. February 9th 2021.

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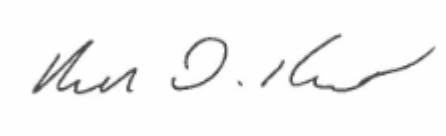

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# Executive Summary

This report provides analysis of operations, best practices and recommendations at a standalone COVID-19 vaccination center. We observed the physical layout, patient flow, vaccination preparations and staff interacts at the vaccination center at Bloch Arena, a basketball and event facility, onboard Joint Base Pearl Harbor–Hickam, administered by the Naval Medicine Readiness and Training Command, Pearl Harbor, (NMRTC-PH) for the U.S. Navy community on Hawai'i.

Vaccination centers comprise two interfacing processes, (1) the flow of community participants to be vaccinated and (2) the preparation and administration of vaccine doses. The process steps include the following:

- **Vaccine preparation:** Medical or lab staff are required to thaw and mix vaccine on site. This process takes approximately one minute per six-dose vial but can be conducted in batches of up to six vials per thaw cycle to increase efficiency.
- **Pulling vaccine doses:** Trained medical staff draw vaccine doses from the vials into individual syringes for administering to patients. This process takes about four minutes to prepare six doses.
- **Screening participants:** Administrative personnel are required to assess eligibility and ensure that required paperwork is completed.
- **Administering vaccine:** A medical professional checks the medical eligibility criteria of the vaccine participant, verifies the dose and vaccine lots, administers the vaccine, and directs the vaccinee to the checkout.
- **Participant checkout:** Medical professionals collect data sheets from each participant and instruct them on returning for future doses, potential side effects, and the length of time required for observation in a sitting area. They answer any questions the participants who have been vaccinated may ask.

We gathered vaccination preparation and administration rates and examined the workflow system for chokepoints and efficiencies. We found that the vaccination center at Bloch Arena, as implemented on February 2021, can administer about 2,000 doses a day at full flow capacity—perhaps surging to 2,500 doses, but with some risk of error and waste. Beyond that number additional shifts will be necessary.

Our timing and flow calculations indicate that the vaccination center stations are well balanced for smooth and efficient operation; naturally, however, the sporadic arrival of participants to be vaccinated creates surges and lulls in workflow that prevent full efficiency. We posit, though we do not have data to infer, that individuals working at the vaccination center are at risk of fatigue and burn-out, particularly because many tasks are highly repetitive, workers have a high sense of mission and lack of safety related time-limitations, such as a "flight day", to limit exertion. Fatigue and burn-out risk increased errors that may result in wasted vaccine doses.

# Best practices

We make the following observations regarding best-practices from the Bloch Arena vaccination center for consideration by other vaccination centers:

- **Facility access.** Choice of a facility that is well-known and centrally located, with good ventilation and ample parking maximizes inflow of participants. In this case the lack of compliance with the Americans with Disabilities Act (ADA) was noted and addressed to serve non-ambulatory vaccination participants.

- **Flow patterns**. Confusion is inefficient. The center is designed with a logical patient flow. Centers in buildings not designed for patient flow should consider clear markings and linear flow progression that are flexible to allow for improvements to the process.

- **Queue-formation engineering**. The vaccination center's staff considered where and how queues should form. Gaggles or bunched lines can be treacherous for the smooth flow of operations because crossed-lines can foul previous steps in the process. Lines were formed where participants could maximize distance to prevent spread of COVID-19. The queues and movements were kept simple and clear to ease the flow of participants.

- **Staff role specialization.** Borrowing from well-established efficiency practices in industry, the center broke tasks down into an assembly-line process, and assigned personnel to be "shooters", "preppers" and "pullers", "runners", paperwork processors and direction-givers. Specialization allows each individual to focus on their function and skills rather than having to change task numerous times for each vaccination. Staff specialization increases the flow rate and decreases many types of errors.

- **Cross training of personnel**. Most personnel, particularly medical, worked most stations at the center during the week. This ensured they did not become complacent with tedious work and also that they knew the full system, both to suggest improvements and steer confused patients to their next station.

- **Overstaffing at flow nodes.** At each point where participants might get confused about where to go, center staff members were there to direct them. Additional staff might circulate around the observation area (and direct people to the right exits).

- **Constant improvement and innovation.** The vaccination center staff take a flexible approach to operations and look for improvements and efficiencies. An end-of-day "hotwash" allows for rapid implementation of innovations or fine-tuning adjustments. During the days of observation for this study, the process was improved in several ways, such as an added parking lot and line for second doses, and runners to take vaccine from the preparation table to where it would be administered.

# Recommendations

In addition, we offer four recommendations for consideration at this or other vaccination centers:

- Proactively design a work schedule to minimize staff error. Institute a "flight day" work limitation for staff at the vaccination center, especially on the preparation table to prevent fatigue that may result in errors that waste doses.

- Continue to look for steps that delay participants moving through the system and for methods to expedite them at that step. For example, at the Bloch Arena Center, access to electronic health records and an online electronic screening system for individuals to fill in forms and file paperwork prior to arriving at the center would decrease participant time in the system by about six minutes.

- When possible, get a better prediction from commands sending participants to be vaccinated; better estimates of numbers arriving each hour would help smooth out demand and make intake more efficient.

- Identify a dedicated sanitization and social-distancing team to wipe down surfaces and enforce spacing among participants.

There are potential methods to increase the rate of flow through the vaccination center, but many of these would increase the complexity and decrease the flexibility; implementing such methods is not warranted. At this point, the simplicity of the flow is one of the greatest strengths of the center.

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# Contents

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# A Pandemic Vaccination Center

This report describes the vaccination center established by the US Navy at the Bloch Arena on Joint Base Pearl Harbor–Hickam (JBPHH). We base our discussion and recommendations on observations made in February 2021.

Every vaccination center will differ because each must develop its own structure and processes depending on the nature of the facilities, the characteristics of the population being serviced, the manner of service and the specifics of vaccine preparation and administration. The process flow described in this report is from a high-throughput walk-up clinic (versus appointment-based or drive-through) serving a mostly military population and administering the Pfizer-BioNTech BNT162b2 vaccine.

By early February, the vaccination center at Bloch Arena had demonstrated its ability to vaccinate more than 1,500 personnel per day, working at a comfortable pace over a period of seven to eight hours. Several features of the site setup are presented as best practices in this report.

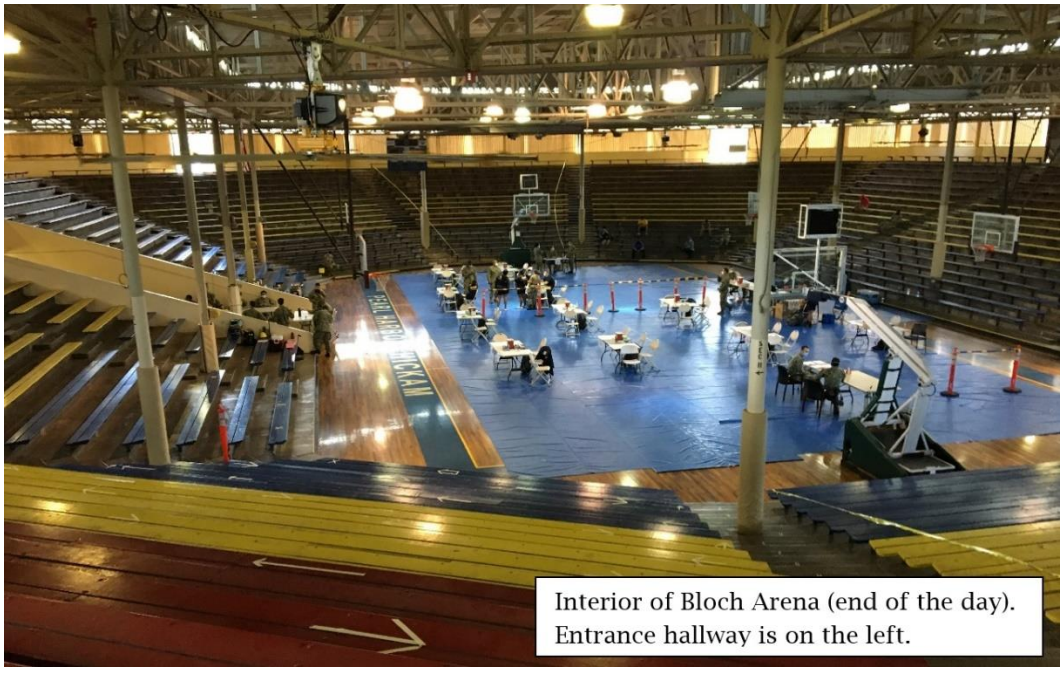
## Site description

The vaccination center took advantage of Bloch Arena, a full size basketball court and bleachers that accommodates approximately 4000 spectators. The arena is well known to community members at JBPHH since it is the site of local sporting events (the Harlem Globe Trotters regularly play here), concerts (Elvis played here in 1961), and command all-hands meetings. The facility is centrally located on Naval Station Pearl Harbor between the main Nimitz gate and the Makalapa Gate. The arena has an adjacent parking lot with spaces for about 250 cars, and is entered through a 50 foot open-air pathway that extends from the parking lot to the main entrance.

The building is wood and steel construction, built in the 1940s. The arena is set into a shallow slope, and the floor of the arena is sunk below grade; there are 10 steps down to the court level from the main entrance. The chair-lift installed on the steps to comply with the Americans with Disabilities Act (ADA) is currently inoperable. The facility uses open-air ventilation rather than air conditioning due to the local climate; however, between jalousie blinds, an overhanging roof, and the hillside, little sunlight penetrates the building. Restrooms are adjacent to the main entrance. The furnishings of the arena are relatively rudimentary: wooden slat bleachers bolted to concrete.

Figure 1. Bloch Arena and parking lot, top: aerial view, bottom: indoors.


Key: A – Parking lot. B – Access control point. C – Entry to the arena.
Source: GoogleEarth, CNA.




Source: CNA

# Methodology

The Navy Medicine Readiness and Training Command Pearl Harbor (NMRTC-PH), designed, established and staffed the Bloch Arena Vaccination Center to vaccinate the US Navy community in Hawai'i. The center was supplied with the Pfizer-BioNTech vaccine. The Center for Naval Analyses (CNA) Field Representative to Commander, United States Pacific Fleet visited the Bloch Arena vaccination center the week of 9 February, 2021, to document the vaccination process, challenges, and best practices.

The processes, stations, and queues at the center were observed, analyzed, and documented. Medical and administrative staff working at the Vaccination Center described their function and methods; these were timed during the normal course of operations. A haphazard sample of participants (i.e. the individuals to be vaccinated) were observed at each station, and the time spent, as well as the time to prepare the station for the next participant, were recorded. We used these observations, explanations, and data to reconstruct system flow.

# Vaccine preparation process

A vaccination center is at the intersection of two processes: the process of personnel flow for administering the vaccine to participating individuals, and the process of developing and distributing the vaccine materiel. The first section describes the materiel development and distribution process for the vaccine, from the manufacturer to the medical professional who injects it into the vaccination participant.

## Packaging, storage, and shipping

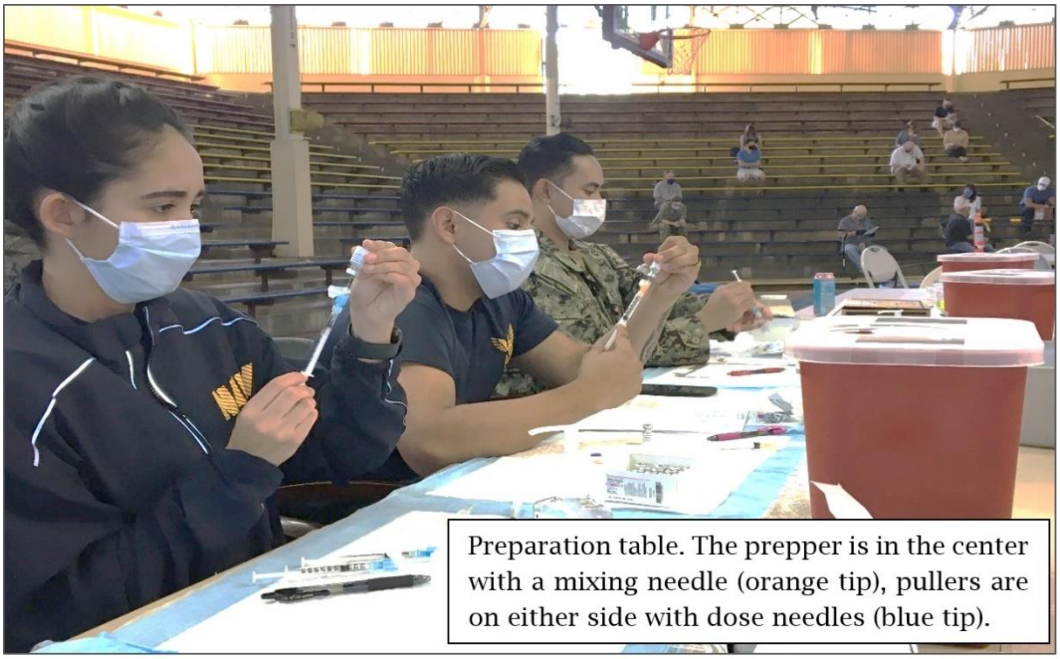
The BNT162b2 vaccine is an mRNA vaccine manufactured and packaged in the Pfizer Inc. facility in Portage, Michigan. This is where the vaccine is placed into the vials for shipping and storage at minus 80˚C. Vials are boxed and shipped in minimum quantities of 195. As labeled each vial is labeled to contains five doses of vaccine but, if measured carefully, six doses can be drawn from each vial. A minimum order provides between 975 and 1,170 vaccine doses.

The vaccine allotment for all military services in Hawai'i arrives at Tripler Army Medical Center (TAMC) on O'ahu and is stored in an ultra-freezer until the vaccination center is ready to receive it. NMRTC staff pick up vaccine from TAMC in the morning and transport it to vaccination centers, stored in insulated cold boxes. The thawing process to either refrigerator temperature (4˚C) or room temperature takes approximately two hours.

## Preparation: preppers and pullers

Vaccine doses are prepared in discrete, time-sensitive steps—a complicated process involving a variety of vials, mixtures, syringes and needles (and re-capping of needles). The Centers for Disease Control and Prevention (CDC) and the vaccine manufacturer provide the protocol for the preparation[1]; however, a protocol is not a work flow process, so teams can tailor the preparation methods to the site and conditions. Attention to detail is important: at least five types of error (including poking yourself with one of the needles) result in disposal of the *entire* vaccine vial. Precise measurement ensures six doses can be drawn from each five-dose vial. This step requires trained and experienced medical or laboratory staff.

**At Bloch Arena** the vaccine preparation takes place at a focal set of tables (labeled "Prep" in Figure 2) staffed by the vaccine preparers. The vaccination center divided the protocol into two jobs so that personnel could specialize: "Preppers" take vaccine from the cool box to dilute it. They then pass the vials to one or more "pullers" who specialize in drawing the vaccine into individual dose syringes.



Preparation table. The prepper is in the center with a mixing needle (orange tip), pullers are on either side with dose needles (blue tip).

Source: CNA

[1] See the section on "How to Thaw, Prepare, and Administer the Pfizer-BioNTech Vaccine" at Centers for Disease Control and Prevention, Pfizer-BioNTech COVID-19 Vaccine, "Vaccines and Immunizations", accessed 17 February, 2021, https://www.cdc.gov/vaccines/covid-19/info-by-product/pfizer/index.html.

The preparation begins with thawed vials of vaccine and diluent (saline to dilute the vaccine). Just prior to use, the prepper takes between one and six thawed vaccine vials from the cold box, checks lot number and expiration date, and "inverts" (rocks gently) the vial ten times to loosen the vaccine. The prepper then draws diluent using a mixing syringe from the diluent vial; the prepper injects the diluent in with the vaccine, equalizes the pressure, and again repeatedly inverts the vaccine vial to mix. The prepper notes the time and passes the vials to one or more pullers.

For each dose, the puller uncaps a needle, draws vaccine using a zero dead-space syringe (different from the mixing syringe used by the prepper), equalizes pressure in the vaccine vial, and recaps the needle now ready for use. The number of vaccine doses drawn from the vial is recorded. The vaccination center had a maximum of two preppers with one to three pullers each.

Specialization creates efficiencies, both in time and skill, and eliminates some sources of error:

- The draw from the diluent into the vaccine vial is a different volume (1.8 mL) than the draw into individual needles (0.3 mL) and the syringes are different sizes; specialization allows the preppers and pullers to focus on the single quantity and one type of syringe.
- Preparing multiple vials at once allows the preppers to mix vials about 25 percent faster.
- Sticking to a single type of needle/syringe per person allows the prepper or puller to focus on the job and perform the same movements in quick succession, rather than constantly switching equipment.

On the other hand, specialization can become tedious with repetition and is itself associated with error. To combat the risk of complacency and disengagement, workers at the preparation tables would sometimes volunteer to give shots (as shooters) or assist with collecting paperwork and instructing newly vaccinated participants at the end of the process. This helped keep staff cross-trained at the vaccination center.

Doses must be used within six hours of mixing, and the vaccine cannot be stored or refrozen after mixing. As a result, the preppers only mix vials when the vaccination center is certain that six individuals are ready for vaccination, and that can result in long wait times if participants arrive infrequently. On the other hand, the preparation process can take time to catch up if many participants arrive together, leading to lines and wait times. This balance is coordinated by the officer in charge of the vaccination center, who stands at the entrance to the floor and monitors the stations and inflow of participants to be vaccinated, and informs the preparation table when new vials and doses need to be prepared.

**Timing**: One prepper could mix a single vial in about one minute (average 64 seconds), whereas mixing six vials took four and a half minutes (average 46 seconds each).

Pullers took an average of 23 seconds to draw out each individual dose. This value was apparently dependent on the skill of the puller, with the most experienced averaging as little as 11 seconds per dose pulled; however, we did not have a sufficient number of each skill level to compare them statistically.

*The sequence of the dose affects the time taken:* The data indicate that the first dose takes longer to draw than the subsequent four doses (an average of 27 seconds for the first dose and 19 seconds for the next four), but this difference was not statistically significant. The sixth dose took significantly longer than the previous five (35 seconds for the sixth, 21 seconds for the first five) and this difference was statistically distinguishable ($t = 2.42$, 49 df, $p < 0.05$). Since the sixth dose requires particular attention and skill to ensure a full dose of vaccine, there is the potential for an additional specialization—a puller who just draws the sixth doses—when the center is particularly busy.

## Injection: runners and shooters

The "shooters" are responsible for injecting the vaccine into the participating individuals. Originally the shooters collected the vaccine from the preparation table; however, this increased the turn-around time for the shooters and traffic on the arena floor. Furthermore, the presence of shooters waiting for doses at the preparation table created stress for the pullers, leading to concerns that pullers might rush and increase errors in drawing vaccine.

This concern led to a specialized "runner" position to distribute vaccine doses from the pullers to the shooters; the runner has a better sense of activity in the system and gets to know when shooters are ready for more doses or a break. When the shooter is ready with a dose, they indicate to the next participant in line. Vaccine injection into the deltoid muscle of the arm only takes three seconds, but the questions and preparation beforehand take about two minutes with questions and preparation. Spent syringes and needles are disposed in a sharps box on the table.

**Timing**: Shooters took an average of about two minutes (114±52 seconds) to vaccinate each participant. The range was between 49 seconds and 258 seconds. Once the vaccinated participant leaves the table, the shooter has to reset, prepare the table, and call the next participant over. On average this took a minute (61 ± 37 seconds), with a range of 15 to 151 seconds—longer times were recorded when the center was not very busy and no participants were waiting for shots.

The throughput for the shooter table, as implemented here, should be modeled as an average of four minutes per vaccination because the data skew right.

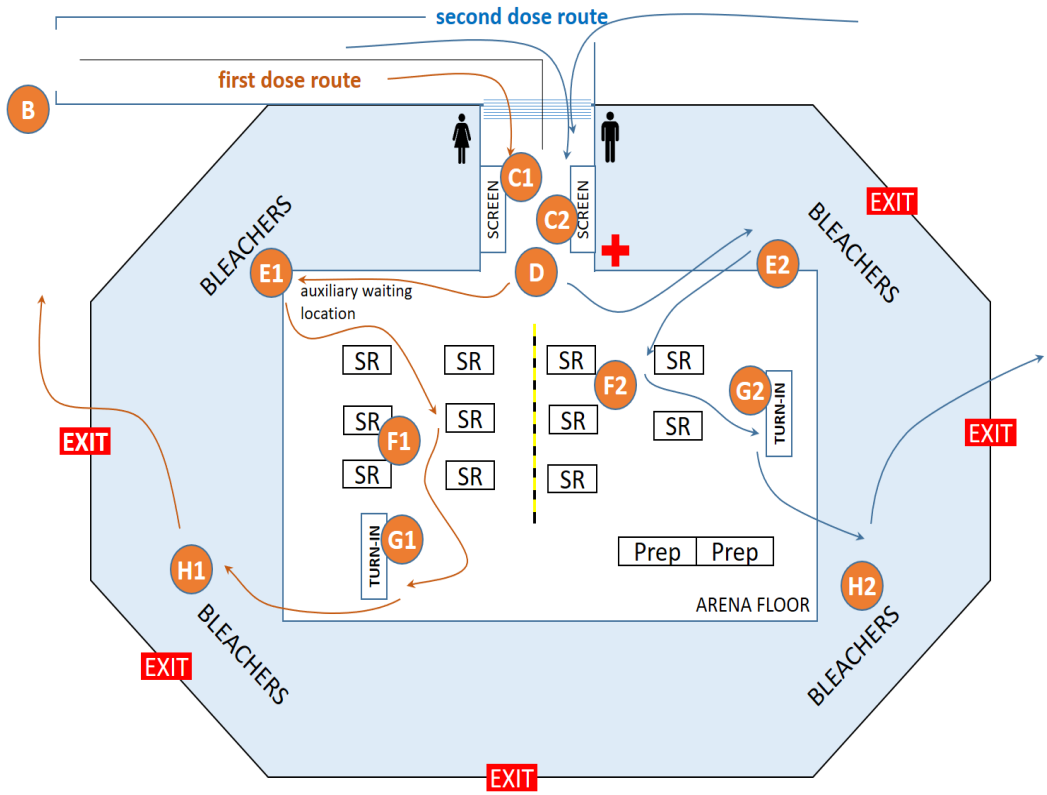
A vaccine dose being administered at the shooter table

Source: DVIDS

# Vaccination participant flow

This section follows an individual participant as he or she works through the vaccination system, describing how the vaccination center staff set up the process flow for first and second doses (Figure 2).

Figure 2. Bloch Arena vaccination center flow, 11 February 2021




**Key:** SR – shooter table where injection occurs, Prep – vaccine dose preparation table.

Example routes are shown for a first dose participant (brown arrows) and a second dose participant (blue arrows). These are examples: there is a great deal of flexibility in the system and any participant can be injected at any shooter table.

B: Access control point,

C: Screening and information tables,

D: Distribution point of individuals to shooter tables.

E: Auxiliary waiting area to prevent lines forming at D and fouling C.

F: Shooter table area.

G: Paperwork turn in and information table.

H: Observation location in the bleachers.

Source: CNA.

# Access control

For the individual participant to be vaccinated, the process begins in the parking lot (labeled "A" in Figure 1), where there is an access control point by the entrance walkway to the arena (labeled "B" in Figures 1 and 2). The control point includes tents and tables and several personnel to direct arrivals; if specific organizations are targeted for vaccination that day, their leadership or administration can set up signs and directions and ensure their own staff are available to assist with the process.

- Individuals arriving for their initial vaccine dose fill in paperwork to indicate their command and eligibility and to state that they are volunteering for COVID-19 vaccination. An administrative staff member reviews this paperwork for eligibility and then directs them down the walkway to the arena, along the "**First Dose**" route (to the right of the path).

  Individuals arriving for a second dose show their vaccination card and are directed down a "**Second Dose**" route (to the left) along the path into the arena. To accommodate the increased number of second dose participants, the vaccination center provided parking on the other side of the arena and a second access control point and entry route for this population.

The large area provided for the access control point is ideal, allowing multiple awning tents and tables, so that several organizations can spread out to provide support for their personnel arriving at the vaccination center. The transition to the walkway entrance to the arena provides a discrete boundary that is effective at preventing individuals from wandering into the vaccination center without authorization.

**Screening paperwork and vaccine education information** are available at the access control point and later in the arena entrance. Two forms are required: a special form developed by the NMRTC-PH asking for name, DOD id number, and background information; and a Defense Health Agency COVID-19 vaccine screening and immunization document (DHA Form 207).

Ideally these forms would be available online prior to the visit, and tied to electronic health records accessed at the vaccination center by scanning a CAC card, but the vaccination center did not have the necessary information technology, so hand-filled forms were used. On the other hand, the paperwork provides a tangible item for participants to hold on to during their visit; and turning it in at the end ensures that they check out appropriately with the center.

**Timing**: The time to fill in forms was a hard value to capture. Nine individuals were observed filling in their forms, taking an average time of about four minutes (235 seconds ± 45); the quickest was just over two minutes (140 seconds), and the longest was about four and a half minutes.

The routes for first and second dose vaccine participants proceed down the 50 meter walkway to the arena main entrance (labelled "C" in figure 2) and the screening desks. Signs on the pathway encourage social distancing, and the length of the path allows a queue to form in the event that large numbers arrive together, with appropriate distances between individuals. Anecdotes of early vaccination sessions described the line as stretching out of this area and along the side of the parking lot (where there is sufficient space to accommodate a long line).

The line at this stage is open to the elements, so rain or intense sun would make the experience uncomfortable. The vaccination center staff therefore attempt to overstaff the screening desks at the next step to bring participants into the arena and arrange an indoor queue system for first and second dose recipients.

## Screening

From the pathway, the route turns right, through the main arena entrance gate and down 10 steps into the short entrance hall on the arena-floor level (labeled "C" in Figure 2). Individuals to receive a first dose are on the right and are directed to screeners sitting at tables to the right side of the entrance; individuals to receive a second dose are directed to screeners seated at tables to the left. **In the event of heavy traffic the tables on the other side of the hall can switch to assist either group**.

The screener checks the forms, asks some additional straight-forward questions (e.g., "what arm do you want the shot in?"), and answers any questions the participant may have about flow. The screener also fill in the lot number, and the date for the second vaccination on the vaccination card. Originally the screeners were medical staff, but because medical personnel were needed elsewhere, the screening position was staffed with sailors on limited duty. Screeners call over a medical professional if the participant has other questions. The screener directs the participant to the distribution point on the arena floor (labeled D).

**Timing**: The average time taken at this table was variable but generally about 2 minutes (average 131 ± 60 seconds). Older civilians tended to take longer than others (such as service members), but data were insufficient to establish that conclusion. A bimodality in the data is explained by experience: participants being screened for their second dose took a shorter time than those being screened for their first dose (143 vs 107 seconds, t test, $p < 0.05$).

The screeners did not need a lot of time between participants to "reset" their station—generally just a couple of seconds.


Source: DVIDS

## Distribution point

Several center staff members are positioned at the entrance to the arena floor (labelled "D" in figure 2) to direct vaccination participants to a free shooter table on the arena floor (labeled "SH" or "F" in Figure 2). If a shooter table is free and ready to administer vaccine, then the participant is sent directly to that table. However, the desire to shorten the outside line, and the limitation on vaccine production, can result in a wait for an open shooter, so dose groups might be directed to wait in a queuing area on either side of the entrance in the bleachers (labeled "E1" and "E2" in Figure 2).

**Pacific Fleet leadership determined that individuals ready to take the second dose of the vaccine have priority over initial doses. The dual lines allow the vaccination center coordinator to identify second dose individuals as they enter the arena and make that prioritization immediately prior to the point of vaccination.**

This auxiliary queuing area is a key regulator for the system. If the system gets busy and the preparation table takes time to respond, the shooter tables will fill up with participants waiting for vaccine doses. As soon as the shooters have the vaccine doses, the waiting participants will quickly get injected and move out in a wave of six, 12, or 18 (based on the number of vials prepared); the auxiliary queueing area ensures that larger groups of participants are ready to take their spots. Placing the line to one side of the arena, rather than at location D is important: a gaggle or line of people waiting at D would stretch into the entrance hall area, fouling the screening process.

The officer running the vaccination center is generally located at the entrance to the arena floor (labelled "D" in figure 2), supervising and helping direct participants to shooter tables. From this location, he or she can maintain communication flow from the entry process to the preparation tables; that ensures the preppers know to draw more doses at busy times and slow down when it becomes less busy.

## At the shooter table: where the needle meets the arm

Eleven shooter tables are spaced out across the arena floor, generally positioned around the preparation table. The table arrangement allows for social distancing and offers line-of-sight to either the entrance hall (labelled "D" in figure 2) or the queuing area (labelled "E" in figure 2). It also allows for easy access to the preparation table. The physical arrangement additionally limits cross traffic of participants as they move to their designated shooter table or move on to the paperwork stations afterwards.

At each shooter table, two medical personnel administer shots (not all were staffed all the time), with a chair on either side where participants sit, arranged with the expectation that the shot would be administered into the left arm. All tables are identically equipped with a sharps-disposal box, hand sanitizer, a box of vinyl gloves, and a trash receptacle. The front of each table displays a number to help direct participants to the right place.

The vaccine and process to administer the first and second doses are the same. However, vaccination center staff divide the tables loosely between the two groups, with a flexible barrier between them (the black and yellow line in Figure 2). Moving the barrier helps keep the participants in their dose streams and also indicates the level of priority, keeping the line shortest for the second dose participants in accordance with commander's intent to prioritize second doses. That said, the center staff were not restricted to this set up and first dose participants might be directed to an open shooter table in the second dose area depending on how busy the center is.

**Timing**: On average, participants spent about two minutes (114±52 seconds) at the shooter table. The range was between 49 seconds and 258 seconds. We removed one value from the analysis because the participant asked to consult the on-scene doctor. In some cases, the vaccine dose was not at the table when the participant sat down, so the shooter had to wait for the runner to deliver one from the preparation table. We did not find a difference in the time taken at the shooter table for participants who were receiving first versus second dose.

Participants spent about three quarters of their time at the shooter table (average of 85 seconds) preparing for the shot, with the shooter asking questions and the participant baring his or her upper arm. The time after the shot (average of 30 seconds) was spent replacing outerwear and being directed to the data collection point.

## Data collection and checkout

After administering the vaccine, the shooters direct vaccinated participants to check out at the "data turn-in" table (labelled "G" in figure 2). Generally, two or more medical personnel work at this table. They ask if the participant has questions and—at the first dose table—remind them to return in 21 days for the second dose. They separate the medical forms from the care instructions that are handed back to the newly vaccinated individual. The medical forms are collected and sent to NMRTC-PH. Access to electronic health records at this point would require more staff to work this station and potentially risk back-up, but would expedite data entry and should be considered for future testing.

We observed that a queue forms at the checkout, especially when vaccinations take place in waves or a worker goes on break. Personnel from the preparation table will often take a break from their syringes to assist with long lines. Work at the data turn-in table can be tedious because it involves repeatedly telling people the same thing.

**Timing**: Time spent at this table ranged from 12 seconds to 87 seconds (n = 23), with a mean of 31±10 seconds per participant.

## Observation area

The checkout staff instruct the vaccinated participant to proceed to the observation area bleachers at the back of the arena (labelled "H" in figure 2) and wait at least 15 minutes to ensure no severe allergic reactions occur.

For each individual to maintain three feet of space around themselves (ensuring six feet of separation between individuals) there must be 30 square feet per person. The observation area for the 15-minute wait was approximately 3,000 square feet for each dose stream, allowing for about 100 individuals on each side (200 total).

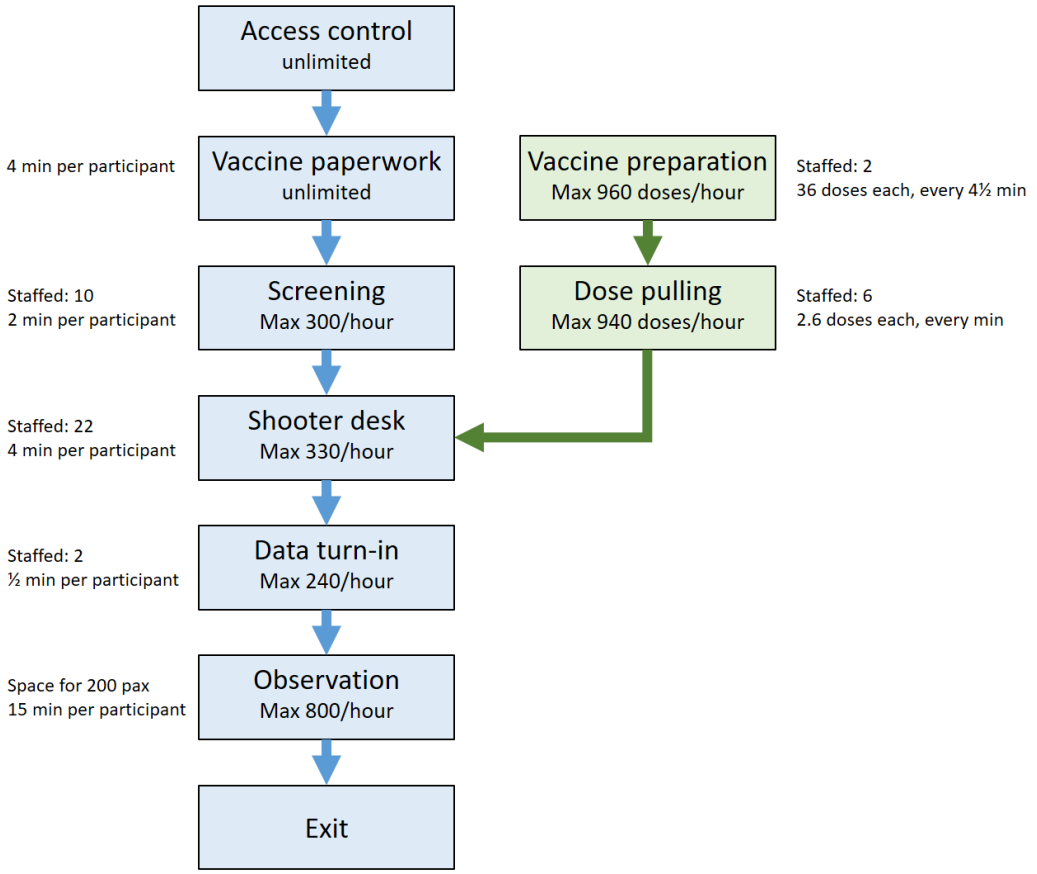
# Disability accommodation

The chair-lift for non-ambulatory participants was inoperable during our observations of the vaccination center, so accommodations were necessary for these individuals. The access control point personnel would keep the individual in the parking lot and collect a shooter to vaccinate them and then observe them in that location for the required 15 minutes. Because this vaccination center serves a US Navy community, relatively few participants have been non-ambulatory; centers serving a more diverse population will need to consider how they will provide alternative accommodations for non-ambulatory personnel if the facility is not ADA compliant.

# Flow Rates

The data collected on the time spent at different stations suggests a maximum flow rate for the center of about four individuals vaccinated per minute with a staff of about 60 (Figure 3) with the potential to surge up to six. This amounts to 240 to 360 per hour or about 2,000 to 2,500 per day assuming eight hours of constant, intense operation.

Figure 3. Bloch Arena vaccination center process: doses per hour per staff, 11 February 2021




Source: CNA.

The flow rate analysis indicates that the steps are currently well balanced. The indicated rate-limiting step is the data turn-in, and staff working check-out are often assisted by medical personnel from the vaccine preparation table when they fall behind. Additional screening personnel or processes may allow quicker flow.

Several center staff said that vaccine preparation is the rate-limiting step; our analysis indicates it is not—the impression probably stems from the erratic nature of the demand for vaccine when the center is not running at full capacity: since vaccine is not prepared until participants show up for vaccination, and since participants may show up in large groups. This results in the vaccine preparers scrambling to produce the doses required as the participants are exiting the screening process and starting to queue. Fortunately, even though this causes a delay, the vaccine producers can generate large numbers of doses relatively quickly and get the system flowing.

As a result, we would not recommend changing the vaccine preparation capacity relative to the capacity of other stations. We also would not necessarily recommend leaving it static if the number of shooter tables is increased: the vaccine production is the most complicated and technical step, and fatigue-related errors are expected if it is run at "full capacity" for long periods.

Recent data indicate that the center is currently administering a peak of almost 1600 doses a day—about two thirds of the predicted capacity. Limited doses of vaccine may explain why the vaccination center is not operating at full capacity, but it may also be limited current demand, since some vaccine remained in the insulated storage at the end of the day.

The split of vaccine dose administered during observations was approximately 1000 first doses and 300 second doses. The additional capacity (i.e. 400 to 900 doses daily) should be available to continue this rate of first doses, maximizing in about three weeks when the 1000 first-dose vaccinees return for their second dose.

# Daily schedule

Different days have different schedules, depending on the amount of vaccine—both remaining from the previous day and newly delivered to TAMC. The communities targeted for vaccination also affect the flow rate significantly: large differences in the predicted and actual numbers of participants showing up to be vaccinated can throw a wrench into the schedule.

Generally, the day begins with vaccination materiel preparation at the NMRTC-PH headquarters (HQ) building—packing of syringes, needles, gloves, hand-sanitizer, alcohol wipes, paperwork, etc., for transportation to the vaccination center. This generally starts around 0600 or 0630. A separate team travels to TAMC to collect vaccine.

The center set up takes place starting around 0700 with doors opening between 0730 and 0740. A break around 1100 coincides with a lull in participants. This break allows staff to finalize paperwork and send it up to NMRTC-PH HQ for entry.

The center secures between 1430 and 1530; materiel and leftover vaccine are returned to NMRTC-PH for protected overnight or weekend storage. Staff reported that the process of storing the vaccine and materiel takes until around 1700 or 1730.

# Staff personnel

The vaccination center functions with approximately 60 staff, but there are daily fluctuations and regular modification for efficiency.

About half the personnel (all from medical/dental) work in vaccine distribution. This group includes as many as 22 personnel administering injections (shooters), eight preparing doses (preppers and pullers), and two runners distributing vaccine from the preparation tables to the shooters.

The other personnel work in administration and control. As many as 14 work in administration, including up to 10 screeners, who are generally not medical personnel, and the two to four individuals at the data turn-in table who, are medical personnel.

Control personnel account for another 10 or 12 individuals, few of whom require a medical background. This includes the two staff working the access control point, about six individuals at the distribution and queue heads to point participants to the right place, and the O-5 officer in charge of the center. The control personnel also include an O-3 medical doctor who is available for consultation or for emergencies (note that several of the shooters were O-6 medical doctors). Most of the non-medical staff at the vaccination center are personnel on limited duty recovering from injury.

All staff were responsible for sanitation of their work environment. However, the center might benefit from a dedicated sanitation-and-spacing team of about five.

## Workload and burnout potential

The most involved personnel are working 12-hour days when the center is operating, often conducting technical tasks that require precision and concentration that may become tedious. These individuals are highly motivated but there is currently no limit to the number of hours they can work, giving rise to concerns of fatigue or burnout among them as long days and weeks compound.

Notably, the individuals most involved in the center processes are also involved in collecting vaccine from TAMC and collecting and returning/storing materiel at NMRTC-PH HQ, resulting in repeated long days for those staff. Even though the vaccination center is only operating seven to eight hours a day, the staff with the greatest dedication may work 10 to 12 hours. As operations continue, fatigue may be a concern, particularly since those individuals may be involved in vaccine production.

# Process improvement

The personnel working at the vaccination center were constantly working on the flow system and methods to improve and simplify them. Even during the week of observation, several changes increased efficiency, such as opening an additional parking lot and increasing the staff specialization.

After every day, when the vaccine supply was exhausted, the staff would meet to "hotwash" (debrief) the day's operations. Innovations that had been implemented were discussed and either approved for continuation, improved, or abandoned. The most common topic of conversation was the formation of queues and how to best direct the participants to form and work through them. The hotwash process solicited ideas from the center staff and allowed them to be rapidly implemented or rejected.

# Conclusion

The staff and leadership of the center have implemented effective processes both to run the vaccination center efficiently and to develop and incorporate innovations for greater efficiency and simplicity, with a relatively small number of personnel.

## Best practices

The following list summarizes best practices identified in this report:

- **Facility access.** Choice of a facility that is well-known and centrally located, with good ventilation and ample parking maximizes inflow of participants. In this case the lack of compliance with the Americans with Disabilities Act (ADA) was noted and addressed to serve non-ambulatory vaccination participants.

- **Flow patterns**. Confusion is inefficient. The center is designed with a logical patient flow. Centers in buildings not designed for patient flow should consider clear markings and linear flow progression that are flexible to allow for improvements to the process.

- **Queue-formation engineering**. The vaccination center's staff considered where and how queues should form. Gaggles or bunched lines can be treacherous for the smooth flow of operations because crossed-lines can foul previous steps in the process. Lines were formed where participants could maximize distance to prevent spread of COVID-19. The queues and movements were kept simple and clear to ease the flow of participants.

- **Staff role specialization.** Borrowing from well-established efficiency practices in industry, the center broke tasks down into an assembly-line process, and assigned personnel to be "shooters", "preppers" and "pullers", "runners", paperwork processors and direction-givers. Specialization allows individuals to focus on their function and skills rather than having to change task numerous times for each vaccination. Staff specialization increases the flow rate and decreases many types of errors.

- **Cross training of personnel**. Most personnel, particularly medical, worked most stations at the center during the week. This ensured they did not become complacent with tedious work and also that they knew the full system, both to suggest improvements and steer confused patients to their next station.

- **Overstaffing at flow nodes.** At each point where participants might get confused about where to go, center staff members were there to direct them. Additional staff might circulate around the observation area (and direct people to the right exits).

- **Constant improvement and innovation.** The vaccination center staff take a flexible approach to operations and look for improvements and efficiencies. An end-of-day "hotwash" allows for rapid implementation of innovations or fine-tuning adjustments. During the days of observation for this study, the process was improved in several ways, such as an added parking lot and line for second doses, and runners to take vaccine from the preparation table to where it would be administered.

# Recommendations

Most recommendations developed on the first day of observations for this study had been independently proposed and implemented by the vaccination center staff by the last day of observations, a testament to the rapid learning in place.

We offer four recommendations for consideration by this or other vaccination centers:

- Proactively design a work schedule to minimize staff error. Institute a "flight day" work limitation for staff at the vaccination center, especially on the preparation table to prevent fatigue that may result in errors that waste doses.

- Continue to look for steps that delay participants moving through the system and for methods to expedite them at that step. For example, at the Bloch Arena Center, access to electronic health records and an online electronic screening system for individuals to fill in forms and file paperwork prior to arriving at the center would decrease participant time in the system by about six minutes.

- When possible, get a better prediction from commands sending participants to be vaccinated; better estimates of numbers arriving each hour would help smooth out demand and make intake more efficient.

- Identify a dedicated sanitization and social-distancing team to wipe down surfaces and enforce spacing among participants.

There are potential methods to increase the rate of flow through the vaccination center, but many of these would increase the complexity and decrease the flexibility and so are not warranted. At this point simplicity is more valuable than increased efficiency in the system.

**This report was written as part of the CNA Field Program.**

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