

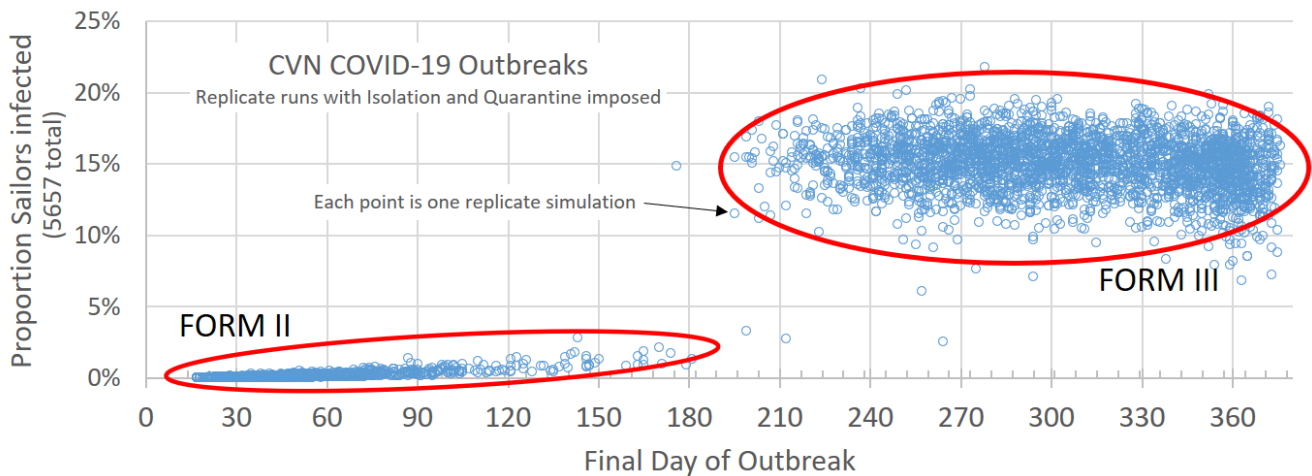
# Model projections: Expected timelines and infection impact for an outbreak of COVID-19 on a USN capital ship

*Insidious* is an agent-based simulation model of infectious disease spread on US Navy ships, developed at PACFLT in March 2020 as a collaboration with CNA, NEPMU-6 and NMCPHC, described at the end of this document.

## Findings

Based on model results, there are two important forms of COVID-19 outbreak that can take place on a large USN ship (see chart). Form II are contained outbreaks; Form III are uncontained outbreaks. In both cases isolation and quarantine are effective at reducing the overall number of infected sailors but tends to extend the outbreak in time (see previous report). Form I are outbreaks that do not spread, not considered here.

***We assume here that isolation and quarantine measures are imposed rapidly and effectively.***



Model projections indicate that with isolation and quarantine imposed that 27% of outbreaks will follow the large-scale Form III trajectory, while 35-40% will follow the contained Form II trajectory (on the chart above, Form III appears more common because they are more spread out).

The table below shows the expected numbers and projected total sick individuals for the different outbreaks on different classes of ship.

<i>With rapid and effective isolation and quarantine imposed</i>	Projected Duration (days)				Projected Totals (persons)					
	Expected	min	max	Peak day	Infected	Symptomatic	Critical	Attack rate	Debilitated	
<b>Contained (Form II)</b>										
LHA/LHD	80	19	– 144	36	54	2.2%	27	5	2	
CVN	100	22	– 146	42	60	1.1%	30	6	3	
<b>Uncontained (Form III)</b>										
LHA/LHD	254	168	– > 365	103	473	19.4%	181	39	16	
CVN	310	223	– > 365	145	921	17.2%	374	79	30	

## Impact to operations

The *Insidious* model uses the CDC/HHS-recommended parameters to predict the number of sick individuals who will become *symptomatic* and display mild influenza-like (ILI) symptoms (about half are *asymptomatic*); *debilitated*—those with severe ILI symptoms that we assume will be unable to continue their duties; and *critical*—those that require hospitalization and treatment and are most at risk of death.

- **The projected numbers of expected debilitated individuals even in the largest outbreaks are a small fraction—less than 2%, of the crew in total**

*However, this is not the full impact to the crew:* In this model the sick (including the debilitated) are isolated and their contacts are quarantined. These individuals are unable to perform their duties to the ship and can be a large proportion of the crew (table below). For “contained” outbreaks the numbers are similar between the CVN and LHA/LHD because the outbreak was not limited by population. In the uncontained outbreak the CVN has approximately twice the number of cases, but proportionately they are similar.

	Maximum in Isolation per day			Maximum in Quarantine per day		
	Expected	Range	Peak day	Expected	Range	Peak day
<b>Contained (Form II)</b>						
LHA/LHD	16	1 – 32	86	132	11 – 229	87
CVN	16	1 – 35	89	133	11 – 286	92
<b>Uncontained (Form III)</b>						
LHA/LHD	164	49 – 223	254	1025	365 – 1270	252
CVN	394	300 – 495	264	2497	2030 – 2911	270

- **Isolation and quarantine of 50% of the crew is probably not feasible, other measures will be required to control large-scale, Form III outbreaks**

Finally, a ship with an outbreak must be able to move the critical cases to hospital ashore, requiring it to remain within the range for medical evacuation, or incur an increased mortality risk. For the CVN this was as many as 5 individuals on about day 121; for the LHA/LHD it was 3 individuals around day 107.

- **Spatial impact to operations: Ships with outbreaks are tethered to a higher-level medical facility**

## Recommendation

**Develop protocols/rules-of-thumb for keeping capital ships deployed or bringing them to a safe haven or enclave in the event of COVID-19 outbreaks of different size.**

**NOTES:** 1. We are continuing research to distinguish between Form II and Form III outbreaks early in the process to allow more time for planning. 2. The inference of these results is based on data obtained from one CVN and one LHA. The patterns of outbreaks between the two was quantitatively similar, suggesting a general inference in outbreak control patterns. **However, these results cannot be generalized to other classes of ship. We are acquiring additional data.**

## Model description and validation

*Insidious NAIAD* is an agent-based stochastic simulation model of disease spread on Navy Ships, developed at PACFLT in response to the COVID-19 pandemic. The model disease transmission kernel is based on highly structured “sufficient contacts” among personnel on the ship: some in berthing, workspaces, mess, etc. with a probability of transmission at each contact; this structure is parameterized using berthing data from the ship or ship class investigated. The model includes a symptoms engine to drive and track the effects of disease on different elements within the ship. The model in this case was parameterized based on data provided by the CDC/HHS to disease modelers to ensure alignment between models. The implementation of spread and mitigations were designed to match the experiences of Navy epidemiologists who have previously investigated infectious disease outbreaks on US Navy ships.