Gateway Testing and Quarantine Capacity

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We provide this updated modeling analysis of gateway testing and quarantine / isolation capacity prompted by three recent events: COVID-19 prevalence has risen in parts of the U.S. since we wrote our report in June; a potential lack of test access for some Cornell students in their home location; and the recently instituted requirement that people coming to NY State from some high-prevalence areas must self-quarantine upon arrival regardless of test results[1], along with the change in Cornell policy that this necessitated.

In light of these events, we see three challenges for gateway testing and quarantine capacity:

1. Thousands of students will need to come to campus 2 weeks before classes start, which could introduce imported cases to Ithaca and spread the disease in the absence of regular screening.
2. Isolation capacity will be needed for students testing positive during move-in and isolation / quarantine capacity will be needed due to missed cases.
3. Gateway testing must prevent the rise in cases elsewhere from having significant negative health consequences in Ithaca.

Our analysis studies the effectiveness of gateway testing for addressing these challenges. Before summarizing these challenges, we call out two caveats.

First, the numbers in these observations are estimates predicated on a number of assumptions detailed later in this report. Insofar as our assumptions differ from the eventual reality, these projections will differ from reality. For succinctness, we provide our best estimates without repeatedly communicating this source of uncertainty. In addition, in several places we report results to several digits of precision. We do this to support comparisons between different options that are close in value, not because we believe that our estimates are accurate to anywhere near this level of precision.

Second, we model students not currently in Ithaca as arriving in two phases:

- Phase 1: the roughly two-week period before classes start (on Sep 2) when students from high prevalence states will need to self-quarantine;
- Phase 2: and the period starting August 23 when students from other states will perform a phased move-in along with the 18 days after during which we expect the campus to reach steady state.

[1] Connecticut allows a negative viral test result as a substitute for quarantine (link), but New York explicitly states that this is not allowed (link).

In reality, these two phases overlap substantially. However, to enable prediction with our current simulation code, we assume instead that all students arriving in the second phase arrive at once, on August 29, which would normally be move-in weekend. We believe that the main effect of this approximation is to produce estimates for peak quarantine capacity that are more pessimistic than reality, since reality allows some of the isolations and quarantines starting from students arriving on August 23 or shortly after to have completed by the time other isolations and quarantines during phase 2 have begun. Going forward, we refer to “move-in weekend” with an understanding that in reality move-in is more dispersed.

We now summarize our main observations:

- Health Outcomes During Phase 1 (Self-quarantine period): In the gateway testing for students returning from high-prevalence states, we estimate that 100 students will be isolated immediately due to positive test results. During the 14-day mandatory self-quarantine period following their arrival, among self-quarantined students, unquarantined students and faculty / staff already in Ithaca, 17 people will get infected (8 identified and isolated, 9 not identified at the end of the 14-day period). Across both gateway testing and the 14-day self-quarantine period, 120 individuals will be isolated and the total number of infections will be 141. For comparison, 110 of these infections will be infections that occurred in this population of students before they arrived to Ithaca and an additional 27 would have occurred under our model in the Cornell population in Ithaca if students from high-prevalence states had not come.

- Health Outcomes During Phase 2: (Peak quarantine capacity during move-in and the 18 days after): In the next period we analyze, gateway testing for students from low-prevalence states who arrive during move-in weekend and the ensuing 18 days, 95 students will be isolated immediately due to positive test results. The number of infections in the entire Cornell population during the move-in weekend and 18 days following is estimated to be 190-300 across the range of sampling methods considered for gateway testing and asymptomatic screening as detailed in Section 4 below. These are in addition to those occurring during the 14-day mandatory self-quarantine period. Among the infections, 97 are estimated to be infections that occurred in this population of students before they arrived in Ithaca and an additional 39 would have occurred under our model in the Cornell population in Ithaca if no students currently living outside of Ithaca return.

- Comparison to a scenario where all students not residing in Ithaca are prevented from returning: We compare the effect of student return against a simple baseline in which no students currently living outside of Ithaca return. While this is not a realistic scenario, given that several thousand students are likely to return even under virtual instruction and Cornell does not have the ability to prevent such students from traveling to Ithaca, it nevertheless provides a useful benchmark. The total number of infections when students return is estimated to be 366. If no students return, the number of infections in the same population (the Cornell community in Ithaca and the students who would have returned

but are instead residing at a family residence or other non-Ithaca home) is estimated to be 273. This no-return baseline does not include the impact of now-unidentified infections on these remote students' family members (which are especially dangerous for those living in intergenerational households), nor the impact on the greater Ithaca area of some students returning illicitly without gateway testing and without follow-up asymptomatic screening.

- Comparison Between Sampling Methods: We compare the number of infections (including those identified through gateway testing) during Phases 1 and 2 across the range of sampling methods considered for gateway testing and asymptomatic screening. We find that it is important to use a high-quality sampling method (e.g. NP or paired NP + AN) for gateway testing. Using NP or dual NP + AN sampling during gateway testing eliminates ~100 infections and ~200 quarantines (this includes quarantines among all students, staff and faculty, not just those for which Cornell would provide housing) compared to using AN alone. Using paired NP and AN sampling during gateway testing may also help students understand more concretely that AN is quite comfortable relative to NP, potentially improving compliance later in the semester. We also consider different sampling methods for asymptomatic screening, but these have little effect on Phase 1 and 2. In other work we have found that AN is acceptable for asymptomatic screening if coupled with sufficient test frequency.

- Quarantine + Isolation Capacity Needed: We focus on the quarantine and isolation housing capacity required, assuming that Cornell will provide such housing (in local hotels) for all student isolations and on-campus student quarantines. Table 0 below describes the average and 90% quantile of the number of rooms needed in each of the 3 phases under two scenarios: nominal and pessimistic. These are similar to the scenarios used in the June 15th report but are not identical. They are described in the body of the article. If Cornell has the ability to flex upward to handle fluctuations, then it may be appropriate to reserve the mean capacity. If, however, flexing is difficult then it is better to reserve an amount equal to the 90% quantile or larger. In Phases 1 and 2, the 90% quantile is closer to the mean than in Phase 3 because person-to-person transmission during the semester causes infections to cluster together in time. Phase 2 ("peak quarantine") has the largest mean quarantine capacity under the nominal scenario, but Phase 3 is largest under the pessimistic scenario due to larger epidemic growth.

Table 0: Summary of quarantine + isolation capacity needed in local hotels. Here, we assume that isolation capacity is needed for all students, and quarantine capacity is needed for students living in dorms on-campus and fraternity / sorority houses off campus.

	Nominal		Pessimistic	
	Average	90% quantile	Average	90% quantile
Phase 1	113	118	142	150

(self-quarantine)				
Phase 2 (peak quarantine)	500	566	800	949
Phase 3 (steady state)	327	417	1305	1795

This document updates a Gateway Testing Analysis released on August 5. The main differences between this version and the previous versions are:

1. A full multi-group simulation model (which includes 8 groups - UG (dorm), UG (other), Graduate (research), Graduate (other), Faculty (student facing), Faculty (not student facing), Faculty (off-campus), Greater Ithaca community), instead of a single-group simulation model, is used to model the 18-day period following move-in, and the entire Fall semester. For a detailed explanation of the multi-group simulation, please refer to the model description (link).
2. We analyze quarantine capacity using the groups provided in this multi-group simulation model. This allows estimating how quarantine + isolation capacity is consumed differently based on the group (on-campus student, off-campus student, non-student) needing to be quarantined or isolated. We also add an analysis of steady-state quarantine capacity.

0. Outline

In Section 1 we first describe the gateway testing protocol in detail, which consists of two phases: (1) a 14-day period when students from high-prevalence states arrive and self-quarantine, followed by (2) move-in weekend when other students arrive and the 18 days following when we control clusters created by cases missed in gateway testing during move-in. Because of modeled non-compliance by self-quarantining students, some cases are modeled as entering the population during the first phase.

Section 2 describes the two sample collection methods: anterior nares and nasopharyngeal.

Sections 3 and 4 provide results for the two phases: (1) the mandatory self-quarantine period and (2) the period including move-in and the 18 days afterward.

In Section 5, to put the impact of students' returning in context, we compare to a simple baseline in which no students currently living outside of Ithaca return. We emphasize that we do not see this baseline as achievable, given the difficulty of enforcing travel restrictions under virtual instruction.

In Section 6 we provide estimates of the quarantine / isolation capacity that we suggest Cornell reserve in three periods: the mandatory self-quarantine period, the move-in and 18 days afterwards, and in steady state throughout the Fall semester.

1. Gateway Testing Protocol

Students from high-prevalence states are planned to arrive in Ithaca two weeks before classes start and begin self-quarantine. Students arriving from other states are modeled as returning during move-in weekend. (As described above, we view this as a pessimistic approximation to the more spread-out move-in planned.) Figure 1 depicts the assumed timeline relevant to the analysis herein.

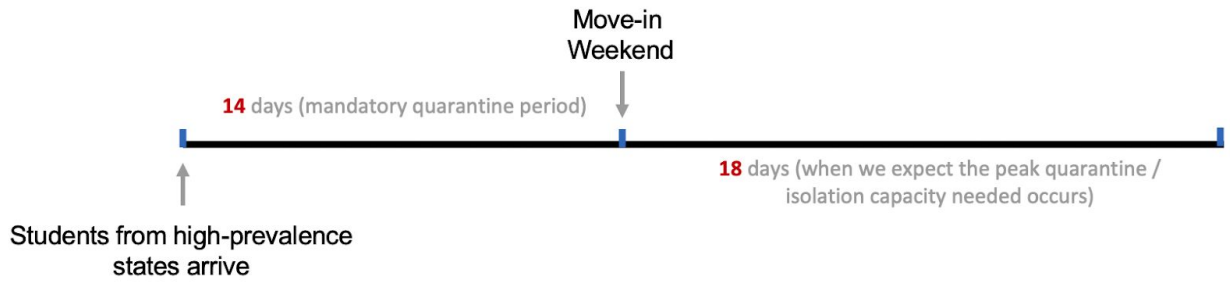


Figure 1: Timeline of the gateway testing protocol.

The gateway testing process over this timeline is assumed to be as follows.

- Some students get tested remotely and are isolated if positive. Others come without being tested. Students coming from high-prevalence states likely will have less test access at home.
- Students traveling to campus risk additional infection after being tested at home prior to departure (if they are tested) and during travel.
- Students are required to be tested upon arrival as a condition for enrollment. Students are strongly encouraged to use the first available testing date, though some will instead choose to be tested later. Positives are isolated, including some false positives. If a student comes from a high-prevalence state, then the student is required to self-quarantine for 14 days.
- Some positive cases already exist on campus due to infections from the greater Ithaca area.
- Some positive cases among incoming students are missed because of false negatives and because some students are early enough in their infection to not be PCR-detectable.
- These two sources of cases (existing and new) combine to create an on-campus prevalence among unquarantined / unisolated individuals.
- This initial prevalence creates additional cases on campus. Some additional cases are also created on campus due to outside infections from the greater Ithaca area.

- The additional positive cases on campus after gateway testing result in additional quarantine & isolation. During the two-week period before the move-in weekend, it is assumed that regular screening has not begun, but contact tracing is underway. During the 18-day period after the move-in weekend, it is assumed that both regular screening and contact tracing are underway.

2. Sample Collection Methods: Anterior Nares vs. Nasopharyngeal

In our analysis, we compare anterior nares (AN) and nasopharyngeal (NP) sample collection methods for PCR testing. We briefly discuss the pros and cons of these two sample collection methods.

Feasibility**:** We consider AN sampling easier to implement than NP sampling.

- AN is less invasive and causes less discomfort than NP. Hence, it is reasonable to expect higher compliance with AN sampling in the context of repeated testing.
- AN samples can be self-collected optionally under the supervision of medical personnel. NP samples must be collected by medical personnel equipped with PPE at centralized testing sites.

Sensitivity**:** Literature suggests that AN may be less sensitive than NP.

- Callahan et al. 2020 reports that nasal swabs tend to produce more false negatives for patients with low viral load who could otherwise be detected using NP swabs. The overall sensitivity of a PCR test on AN swabs was estimated to be 0.8 among symptomatic patients. The meta-review they conducted also indicates the sensitivity of a PCR test with an AN sample is 8% lower than that of a PCR test with an NP sample. They conclude that nasal swabs would be insufficient for diagnostic purposes but would serve well for screening large, mostly healthy populations.
- In our modeling, the sensitivity of a PCR test with an NP sample is assumed to be 0.9 as discussed in the main modeling report (link). The sensitivity of a PCR test with an AN sample is assumed to be 0.6, which is lower than the reported 0.8 sensitivity mentioned above, because (1) in regular screening, an asymptomatic individual tends to have a lower viral load and hence have a larger probability of being missed by a test with an AN sample; and (2) it is likely that Cornell would use observed self-collected AN swabs, which may be less sensitive than swabs collected by a medical professional. When we take both AN and NP samples from the same individual, we assume the overall sensitivity to be 0.92, reflecting the heterogeneity of viral loads in different parts of the body among individuals.

3. Mandatory Self-Quarantine for Students Arriving from High-Prevalence States

Here we model the arrival of students from high-prevalence states for which New York State requires a mandatory 14-day self-quarantine. The students among these that have access to housing in which they can self-quarantine are modeled as arriving in Ithaca two weeks before classes start. Other students in this group without such housing are modeled as either choosing to start classes virtually or, in a few cases, coming to Ithaca without complying with the required

quarantine period in violation of state law. We hope and expect all students will follow the law, but we also understand that some may not and so we include this unfortunate aspect of reality in our model.

Incoming Student Population Sizes: Data available at the time of this report suggest that roughly 33% of the undergraduate students and 23% of the graduate / professional students have homes in states currently designated by NY State as "high prevalence" requiring mandatory quarantine[2]. We assume that many such students with off-campus housing will spend the mandatory quarantine period in Ithaca in that housing. For students that originally planned to be in on-campus housing, we assume that the majority will not come to Ithaca at the start of the semester but rather will begin the semester online; a small fraction will quarantine somewhere outside Ithaca and return during the move-in weekend (discussed in Section 4); while another small fraction will fail to comply with the law, either using non-compliant quarantine in shared housing in Ithaca, or by arriving during move-in weekend without having quarantined. A breakdown of the population (link), assuming that 10% of continuing undergraduates and 75% of continuing graduate / professional students have stayed in Ithaca, yields an estimate of the total number of students arriving 2 weeks in advance from high prevalence states to be ~3750, including ~2500 undergraduate students and ~1250 graduate / professional students.

Compliance: Despite the mandatory self-quarantine order, we do not assume full compliance. We estimate the daily transmission rate to be reduced by 40% compared with the nominal setting. We do this to model several kinds of non-compliance with quarantine. First, some students required to quarantine may do so in non-compliant locations shared with others. Second, some students may break quarantine and have social interaction. Third, although students are asked to be tested on arrival (so that positives can be isolated and monitored so that the danger of transmission is much more significantly reduced), testing will be offered only three times a week so there may be a delay between arrival and the first available test date, and the compliance mechanism uses enrollment in the fall semester and may not be strong enough to have all students be tested right away. This final fact would be better modeled by a testing delay, but unfortunately including this in our gateway testing model would delay this report beyond when it can be useful.

Testing Before Departure: We assume that Cornell will ask students to be tested before departure, but will be unable to mandate this due to a lack of test access for some students. We assume that ⅓ of students from high-prevalence states will be tested at home, and ⅔ from low-prevalence states, both using NP sampling (90% sensitivity).

Testing on Arrival: As discussed above, we assume that students are tested once on arrival. We assume nasopharyngeal sampling with 100% compliance. Because the semester has not begun, and mandatory asymptomatic screening has not started, we assume that no other testing is done.

[2] As of August 5, 2020, 34 states and Puerto Rico are designated as "high prevalence" (link).

Prevalence Estimation for High-Prevalence States: The prevalence level at the origin of students from high-prevalence states is assumed to be 4%. This is estimated by multiplying daily new positive cases, an underreporting factor (assumed to be 10, i.e. for each reported positive case there are 9 positive cases not reported), and the average number of days an infected individual is active (assumed to be 20).

Population Already in Ithaca: The total number of students that either stay in Ithaca during the summer or come to Ithaca early from other "low prevalence" states is estimated to be ~4090 (including ~1130 undergraduate students, ~2960 graduate / professional students). All faculty / staff (of population ~10280) are assumed to remain in Ithaca throughout the summer. The initial prevalence among the group of unquarantined students and the group of faculty / staff is assumed to be 0.1%, which is consistent with the estimated persistent prevalence level in the greater Ithaca area[3].

Interactions: During the two-week period before classes start, we assume no interaction between students and faculty / staff. We use a multi-group simulation consisting of four groups - self-quarantined students, unquarantined students, faculty / staff, greater Ithaca community - to model different behaviors (reflected by daily transmission rate) within and across the groups. As noted elsewhere, we assume 40% compliance with quarantine requirements amongst self-quarantining students. The transmission matrix for the self-quarantine period is summarized in Table 2.

Table 2: Inter- and intra-group transmissions per day during the self-quarantine period, based on the multi-group simulation, which use contacts from the literature, choose an infectivity calibrated to an estimate of R0, and then multiply to get transmission. The table is not symmetric because population sizes differ. Each entry gives the expected number of transmissions per day from one infected member of the row group to each of the column groups.

Group (pop. size)	Self-quarantined Students	Unquarantined Students	Faculty / Staff	Greater Ithaca Community
Self-quarantined Students (3748)	0.031	0.010	0	0.018
Unquarantined Students (4087)	0.0087	0.053	0	0.031
Faculty / Staff (10283)	0	0	0.031	0.027
Greater Ithaca Community (62000)	0.0011	0.0020	0.0044	0.060

[3] Assuming 31 confirmed cases, which is what we have seen over the first 21 days in the month of July, that cases last 20 days, and 2x-4x underreporting in Tompkins County (less than elsewhere due to excellent testing access), gives 60 - 120 active cases, or 0.075% - 0.15% prevalence.

The results are summarized in Table 3.

Table 3: Summary of infections + isolation / quarantine cases within the Cornell population during the self-quarantine period. Quarantine cases include those identified through contact tracing. Isolation cases include those identified through gateway testing upon arrival (including both true positives and false positives) and those individuals who self report. *Existing infected or infected outside Ithaca* refers to either an existing case in Ithaca before the beginning of the period, or an imported case due to student return.

Timeframe & scenario	Size of Cornell pop. in Ithaca	Number quarantined (includes students already in Ithaca + faculty / staff)	Number isolated (includes students already in Ithaca + faculty / staff)	Number free & infectious at the end of the 14-day period (includes students already in Ithaca + faculty / staff)	Prevalence level at the end of the 14-day period (among students already in Ithaca + faculty / staff)	Number of infections (includes students already in Ithaca + faculty / staff)
14-day period following arrival of students from high-prevalence states	7835 students + 10280 faculty / staff	96 close contacts quarantined + ~4K self-quarantined	120 (includes 112 existing infected or infected outside Ithaca)	25 (includes 16 existing infected or infected outside Ithaca)	0.137%	141 total (includes 124 existing infected or infected outside Ithaca)

Due to lack of regular screening, at the end of the 14-day period the prevalence level among the Cornell population in Ithaca is estimated to be 0.137%. The total number of isolated cases is estimated to be 120 as 100 students from high-prevalence states test positive upon arrival in Ithaca. The prevalence level of 0.137% is incorporated into the move-in weekend quarantine / isolation analysis which will be discussed later in this report.

4. Move-in Weekend and the Following 18 Days

In this section we analyze move-in weekend, when students from low-prevalence states return. We also analyze the 18-day period afterward, when most of the clusters created during move-in weekend will have been identified and isolated, and when we expect peak quarantine capacity to arise. When we analyze this period, we assume that the initial prevalence in the Cornell population is equal to the fraction of free & infectious individuals at the end of the self-quarantine period plus those imported cases not identified by gateway testing during the move-in weekend.

Prevalence Estimation for Low-Prevalence States: NYS designates a state as “high prevalence” if its daily reported number of new positive cases exceeds 10 per 100,000 population. Assuming an under-reporting factor of 10 and an average active period of 20 days, this daily-new-positive-case threshold translates to a prevalence level of 10 / 100,000 * 10 * 20 = 2%. Hence, the overall prevalence in student origins that are not designated as “high prevalence” is at most 2%.

Incoming Student Population Sizes: As discussed in Section 3, in addition to students from low-prevalence states we assume that a small fraction (~300) of the students from high-prevalence states that plan to live on-campus will return during the move-in weekend. Although these students will have presumably self-quarantined for 14 days elsewhere, we pessimistically assume non-compliance and consider their prevalence upon entering Ithaca to be 4%. Given it is a small population compared to students from low-prevalence states (with prevalence < 2%), and the assumed under-reporting factor of 10 is large given today's access to testing in low-prevalence states, we assume that the overall prevalence among students returning during the move-in weekend is exactly 2%. A spreadsheet-based breakdown of the population estimates the total number of students returning during the move-in weekend to be ~10770, including ~8180 undergraduate students and ~2590 graduate / professional students.

We use an Excel model (link) to investigate the impact of adopting AN and/or NP in gateway testing / regular screening on the total infection, isolation and quarantine (among all students and faculty / staff) during and shortly after move-in, in light of our comparison of AN and NP above. A multi-group python compartmental simulation was used to model the 18 days following the move-in weekend. The Cornell population is broken into 8 groups, each of which has a different regular screening frequency during the Fall semester, shown in Table 4. The Cornell population during the Fall semester is assumed to be ~30k, which is less than 34k as some students are assumed to not return.

Table 4: Estimation of Cornell population breakdown in Fall 2020 and regular screening frequencies.

Group	UG (dorm)	UG (other)	Graduate (research)	Graduate (other)	Faculty (student facing)	Faculty (not student facing)	Faculty (off-campus)	Greater Ithaca community
Population	4167	7637	2895	3908	3598	1907	4778	62000
Daily Testing fraction	2/7	2/7	1/7	2/7	2/7	1/7	1/30	0

The transmission matrix for the Fall semester is shown in Table 5.

Table 5: Inter- and intra-group transmissions per day in the Fall semester, based on the multi-group simulation, which use contacts from the literature and then choose an infectivity calibrated to an estimate of R0, and then multiply to get transmission. The table is not symmetric because population sizes differ. Each entry gives the expected number of transmissions per day from one infected member of the row group to each of the column groups.

Group	UG (dorm)	UG (other)	Graduate (research)	Graduate (class)	Faculty (student facing)	Faculty (not student facing)	Faculty (off-campus)	Greater Ithaca Community
UG (dorm)	0.21	0.068	0.0017	0.0017	0.017	0.00085	0.00085	0.0017

UG (other)	0.058	0.14	0.0017	0.0017	0.017	0.00085	0.00085	0.0034
GS (research)	0.0032	0.0037	0.068	0.0017	0.020	0.00085	0.0034	0.031
Graduate (class)	0.0024	0.0029	0.0012	0.15	0.017	0.00085	0.00085	0.0034
Faculty (student facing)	0.033	0.038	0.021	0.023	0.017	0.0026	0.0051	0.027
Faculty (not student-facing)	0.0031	0.0036	0.0017	0.0022	0.0048	0.031	0.0034	0.027
Faculty (off-campus)	0.0012	0.0015	0.0026	0.00085	0.0039	0.0014	0.031	0.027
Greater Ithaca Community	0.00019	0.00044	0.0018	0.00027	0.0015	0.00082	0.0020	0.060

Remote Testing: We assume that ⅔ of students coming from low-prevalence states will be tested at home before departure using NP sampling (90% sensitivity).

Local Testing: We assume 100% compliance for gateway testing and 90% compliance for regular screening. We consider the following options for gateway testing and regular asymptomatic screening, with results summarized in Table 6:

- Option 1: Use NP for both gateway testing and regular screening;
- Option 2: Use AN for both gateway testing and regular screening;
- Option 3: Use NP for gateway testing, AN for regular screening;
- Option 4: Use both AN and NP for gateway testing, AN for regular screening.

Table 6: Summary of infections + isolation and quarantine cases within the Cornell population during move-in weekend and the following 18 days, using different gateway testing upon arrival and regular screening policies. Results are rounded to the nearest 10s. Quarantine cases include those identified through contact tracing. Isolation cases include those identified through gateway testing and regular screening (including both true positives and false positives) and those individuals who self report. Note that the number isolated includes roughly 110 to 120 false positives, which in turn lead to 640 quarantined cases due to contact tracing from false positives[4]. These numbers are highly sensitive to the false positive rate of regular screening (assumed to be 0.1% in this document).

Local sampling method	Prevalence in Cornell community after gateway testing	Average number quarantined (includes *all* students + faculty & staff)	Average number isolated (includes *all* students + faculty & staff)	Average number of infections
Option 1 (NP for gateway and screening)	0.144%	840 (includes 640 due to contact tracing from false positive)	310	190 (includes 100 infected outside Ithaca)
Option 2 (AN	0.247%	1130 (includes 640	390	300 (includes

[4] Here we assume 6.08 close contacts quarantined per false positive, divided into the groups that they have contact with in proportion.

for gateway and screening)		due to contact tracing from false positive)		100 infected outside Ithaca)
Option 3 (NP for gateway, AN for screening)	0.144%	900 (includes 640 due to contact tracing from false positive)	330	230 (includes 100 infected outside Ithaca)
Option 4 (AN+NP for gateway, AN for screening)	0.136%	900 (includes 640 due to contact tracing from false positive)	320	230 (includes 100 infected outside Ithaca)

Option 1 is the default option assumed in the June 15 modeling report. Option 1 assumes a false-negative rate (FNR) of 10%.

Adopting Option 2, in which the FNR is assumed to be 40%, the resulting initial prevalence in the Cornell community after gateway testing is estimated to increase by 70%. Such an initial prevalence may pose significant risks to the Cornell and broader communities, suggesting that AN alone is not ideal for gateway testing. Meanwhile, the number of infections / quarantines / isolations during and shortly after the move-in weekend is also projected to increase significantly, which could cause substantial logistical challenges.

Adopting Option 3, the resulting initial prevalence is the same as Option 1 since both options use NP in gateway testing. Meanwhile, even when AN (which is of lower quality) is used for regular screening, the number of infections / quarantines / isolations during and shortly after the move-in weekend is estimated to increase slightly when compared with Option 1. In addition, a comparison between Options 2 and 3 shows the necessity of using a high-quality sampling method like NP in gateway testing.

Adopting Option 4, the resulting initial prevalence is estimated to be slightly lower than Options 1 and 3. This is expected due to the higher accuracy of NP combined with AN. The number of infections / quarantines / isolations during and shortly after the move-in weekend is estimated to increase slightly when compared with Option 1. Other benefits of taking both NP and AN samples in gateway testing are:

1. It enables us to get paired-test data, which could potentially provide more insight on the accuracy of AN samples, especially those taken from low-viral-load, asymptomatic individuals. At the same time, we are already collecting paired NP / AN data which is allowing us to already improve our estimate of AN sensitivity.
2. It should improve compliance with asymptomatic surveillance using AN sampling throughout the semester, when compared with taking only NP samples in gateway testing, because students will realize the difference between these sampling methods, noting the comfort of AN relative to NP.

Across all options, the number of total infections during the move-in weekend and 18 days following is estimated to be slightly higher than that during the mandatory self-quarantine period. This is expected since the simulation model for move-in weekend and 18 days following assumes a full population (~30k people) including students, faculty and staff while the simulation model for the 14-day mandatory self-quarantine period only assumes a population of ~18k including students from high prevalence states, students, faculty / staff already here in Ithaca.

Despite the promising results for Options 3 and 4, we want to emphasize that there is still much uncertainty in using AN samples. In particular, we are concerned about the non-uniformity of infectivity and sensitivity over the course of the disease. Further analysis is underway to find the proper frequency of regular screening using AN, which takes into account the interplay between time-varying infectivity and test sensitivity.

5. Comparison to a Baseline Where No Students Return to Ithaca

To help put into context the impact of students returning in the first few weeks of the semester, we compare to a simple but unrealistic baseline in which *no* students currently living outside of Ithaca return. As we and others have observed, we would not be able to achieve this in reality because Cornell does not have the ability to limit the travel of individuals to Ithaca.

We construct this baseline in pieces.

First, we consider infections among students that will return to Ithaca in reality but would not return in our simple baseline. Many of these students were modeled above as being infected at home before leaving for Ithaca. In our baseline scenario, we model these same infections as occurring. These infections included 110 among students traveling from high-prevalence states and 97 among students from low-prevalence states. In total, this is 207 infections.

Second, we consider infections in the population living in Ithaca. We calculate these infections over two time periods.

The first time period is the 14 days before move-in. We run our simulation including only those students, staff, and faculty modeled as living in Ithaca, without an influx of other students arriving from high-prevalence states. This includes 4090 students and 10280 staff / faculty. Asymptomatic screening has not yet started its frequent regular cadence during this time period. In this simulation we see 12 people isolated, 55 close contacts quarantined, and 15 people free and infectious at the end of the 14 day period for a prevalence of 0.103%.

The second time period is the 18 days after move-in. We run our simulation including the same population already in Ithaca (4090 students and 10280 faculty / staff), without the influx of other students arriving from low-prevalence states. We assume asymptomatic screening (with testing frequencies described in Table 4) during this period. In this simulation we see 74 people isolated (including 31 true positives and 43 false positives), 67 close contacts of true positives

quarantined and 219 close contacts of false positives quarantined, and 8 people free and infectious at the end of the 18-day period for a prevalence of 0.057%.

Table 7 below summarizes the number of infections when students return vs. our simple baseline. When students return, the table assumes paired NP + AN sampling is used for gateway testing. We also assume regular screening using AN samples after the move-in weekend in both scenarios.

Table 7: Summary of infections among Cornell population during the gateway testing, 14-day quarantine period, and 18 days following move-in weekend under two scenarios.

	Average number of infections if students return	If no students returned		
		Infections that happened before students returned	Infections that happened in Ithaca	Total
14-day quarantine period	141	110 (includes students from high-prevalence states)	27	137
Move-in weekend + 18 days after	225	97 (includes students from low-prevalence states)	39	136
Total	**366**	207 (all returning students)	66	**273**

The simulation results suggest that the total impact of bringing students back to Ithaca is 366 - 273 = 93 infections, when compared to an overly optimistic baseline.

6. Estimating Quarantine / Isolation Capacities Cornell Needs to Provide

We estimate the quarantine / isolation capacity that Cornell will need during the 14-day mandatory self-quarantine period, during the peak quarantine period during and shortly after move-in, and in steady state throughout the Fall semester.

We consider the same three phases described at the beginning of this analysis:

- Stage 1: 14-day mandatory self-quarantine period (assumed NP sampling for gateway testing);
- Stage 2: move-in weekend and 18 days following (assumed paired AN + NP sampling for gateway testing and AN sampling for regular screening), assuming pessimistically that all students arrive in the weekend before classes start (although in fact there will be phased arrivals);
- Stage 3: the rest of the Fall semester (assumed AN sampling for regular screening).

Table 8 summarizes our assumptions about whether Cornell would provide accommodations for an individual that is quarantined / isolated.

Table 8: Summary of the actions Cornell needs to take in case of a faculty / staff / student that needs to be quarantined / isolated.

Faculty / Staff or Grad / UG Student	Off-Campus or On-Campus	Isolation or Quarantine or Self-quarantine	Where would the individual be housed?	Would Cornell plan to provide housing?
Faculty / Staff	Either	Any	At their home	No
Student	Either	Isolation	Cornell-provided hotel	Yes
Student	Either	Self-quarantine	Student-provided housing	No
Student	Off-campus (excluding sororities / fraternities) + off-campus non-dorms.	Quarantine	Usually student-provided housing	Case-by-case basis
Student	Dorms + sororities / fraternities	Quarantine	Cornell-provided hotel	Yes

We report student isolations, student quarantines in dorms / sororities / fraternities and student quarantines in off-campus housing (excluding sororities / fraternities, including on-campus non-dorm[5]) in each of the three phases.

We use three sets of parameters (nominal / pessimistic / optimistic). The optimistic and pessimistic sets of parameter values were constructed by taking several parameters simultaneously to either the optimistic or pessimistic end of plausible ranges. Table 9 summarizes the key parameters used in all settings.

Table 9: Parameters for optimistic, nominal, and pessimistic settings. Explanations of the choice of parameter values in the nominal setting can be found in the Multi-group simulation model description

[5] Here we are grouping Hasbrouck with off-campus housing. Most units are either occupied by families or studios / one-bedrooms. There are some units that are two-bedroom apartments shared by non-family members.

(link). If a parameter is not specified here, it is assumed that it takes the same value as in our June 15 main modeling report (link).

Parameter	Optimistic	Nominal	Pessimistic
Prevalence among students from high-prevalence states	3%	4%	5%
Sensitivity of gateway testing	90% using NP sampling; 92% using paired NP + AN sampling		
Gateway testing compliance	100%		
Transmission reduction for self-quarantined students	60%	40%	20%
Average daily transmission rate for an individual in the Cornell community (w.r.t nominal setting)	70%	100%	130%
Infectivity probability for each contact	1.7%		
Daily probability of outside infection from outside greater Ithaca area	0.0012%		
Cases quarantined per contact	3.04	6.08	9.12
Sensitivity of regular screening using AN sampling	70%	60%	50%
Regular screening compliance	90%		
False positive rate of regular screening	0.1%		
Regular screening frequency	Table 1[6]		
Duration of quarantine (days)	14		
Duration of isolation (days)	14		

Figures 10-12 show our model's estimation of capacity required for student isolation and quarantine in steady state. To estimate the steady-state requirements, we only consider simulation results from after the first 4 weeks of campus operation.

Figure 10: Distribution of steady-state student isolations during the Fall semester over 50 trajectories, under different parameter settings.

[6] In Phase 3, it is assumed that student-facing faculty/staff once a week, rather than twice a week.

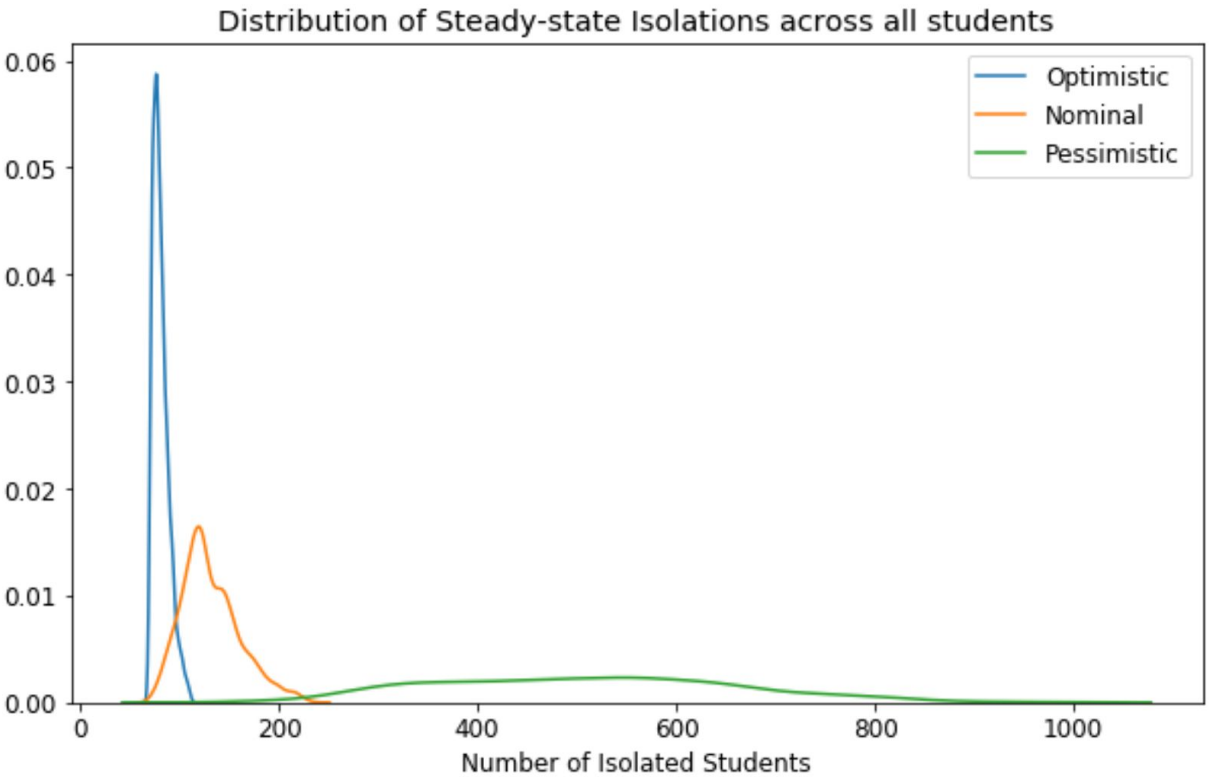


Figure 11: Distribution of steady-state on-campus student quarantines (including undergrads in dorms, fraternities and sororities) during the Fall semester over 50 trajectories, under different parameter settings.

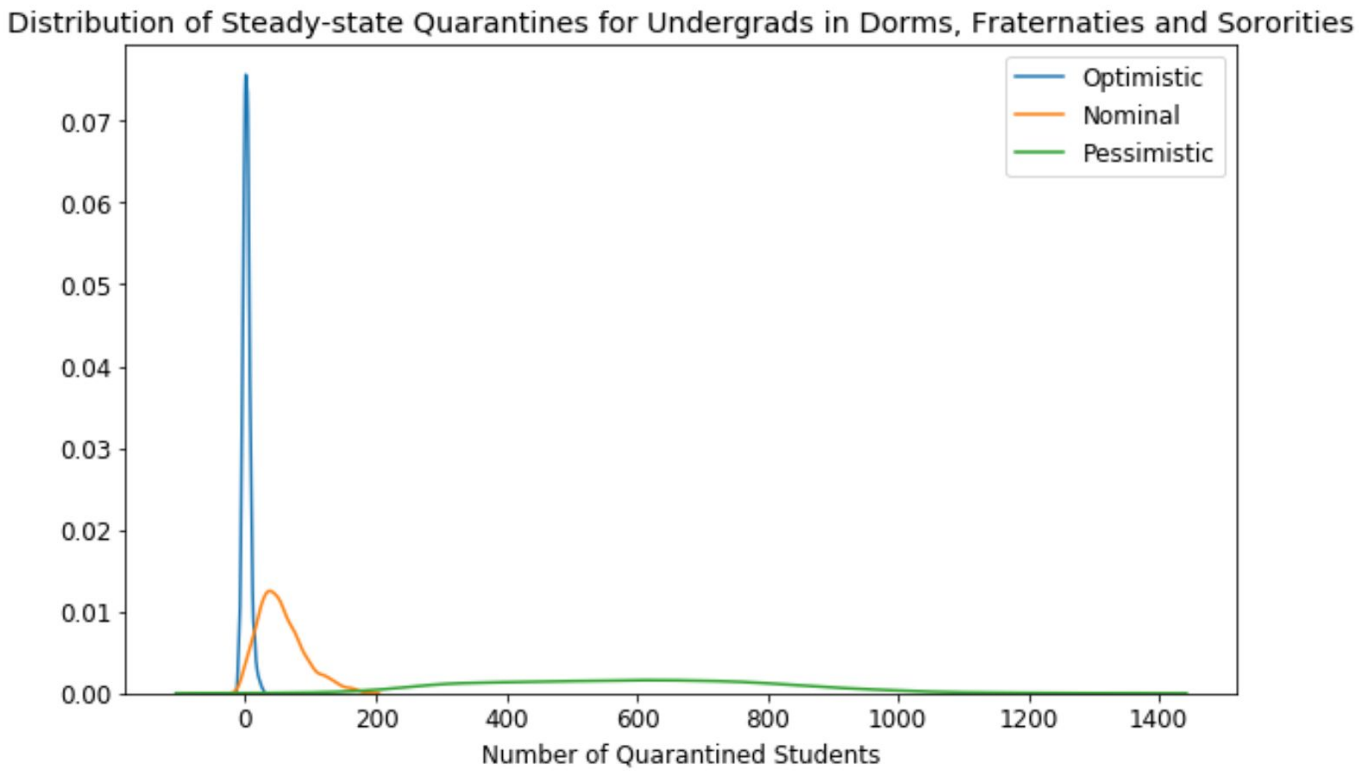
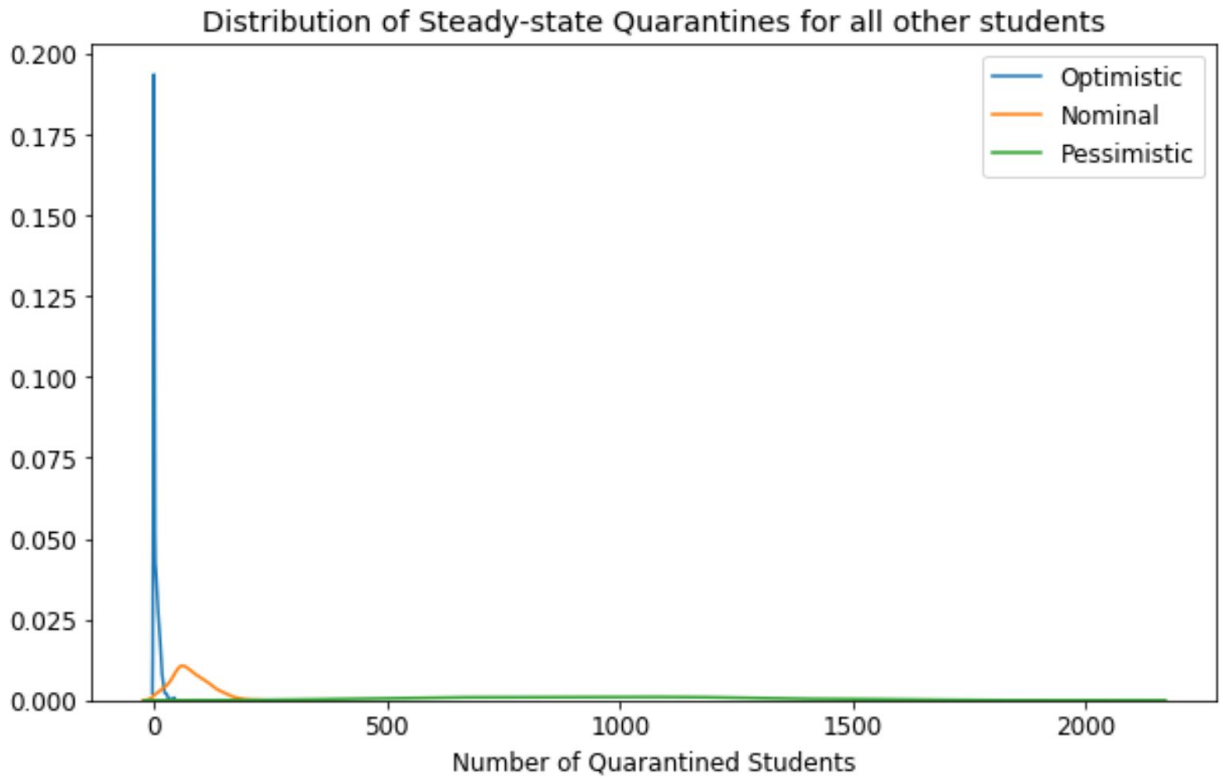


Figure 12: Distribution of steady-state quarantines of all other students (including students living off-campus and graduate students living in Hasbrouck) during the Fall semester over 50 trajectories, under different parameter settings.



We summarize the student quarantine / isolation capacity needed in each of the three phases in Table 13.

Table 13: Summary of average number of student isolations and quarantines during the 14-day self-quarantine period, move-in weekend and 18 days afterwards, and in steady state, under three parameter settings (optimistic / nominal / pessimistic). Quarantine cases include those identified through contact tracing. Isolation cases include those identified through gateway testing and regular screening (including both true positives and false positives) and those individuals who self report.

	Average Student Isolations			Average Student Quarantines in On-Campus Dorms (and fraternities and sororities)			Average Student Quarantines in Off-Campus Housing (excluding fraternities/sororities, including on-campus non-dorm)		
Optimistic / Nominal / Pessimistic	Opt	Nom	Pess	Opt	Nom	Pess	Opt	Nom	Pess
Phase 1 (14-day mandatory self-quarantine period)	86 (includes 76 due to positives in gateway testing)	113 (includes 100 due to positives in gateway testing)	142 (includes 124 due to positives in gateway testing)	N/A	N/A	N/A	24	60	1201
Phase 2	234	269	354	104	231	446	222	508	962

(move-in weekend + 18 days after)	(includes 95 due to positives in gateway testing, 88 false positives in screening)	(includes 95 due to positives in gateway testing, 88 false positives in screening)	(includes 95 due to positives in gateway testing, 88 false positives in screening)	(includes 90 due to contact tracing from false positives)	(includes 180 due to contact tracing from false positives)	(includes 271 due to contact tracing from false positives)	(includes 187 due to contact tracing from false positives)	(includes 373 due to contact tracing from false positives)	(includes 560 due to contact tracing from false positives)
Phase 3 (steady state)[7]	81 (includes 69 false positives)	132 (includes 69 false positives)	509 (includes 69 false positives)	72 (includes 70 due to contact tracing from false positives)	195 (includes 140 due to contact tracing from false positives)	796 (includes 210 due to contact tracing from false positives)	150 (includes 145 due to contact tracing from false positives)	369 (includes 290 due to contact tracing from false positives)	1385 (includes 435 due to contact tracing from false positives)

We assume that Cornell is responsible for providing housing for cases that meet the following criteria:

1. off-campus and on-campus students (including graduate and professional students) that would need to be isolated due to a positive test result;
2. on-campus students that would need to be quarantined due to being a close contact of a positive case.

During the mandatory self-quarantine period, in the nominal setting, Cornell needs to plan for an average isolation capacity of 113; in the pessimistic setting, 142. During the move-in weekend and 18 day afterwards, in the nominal setting, Cornell needs to plan for an average quarantine + isolation capacity of 269 + 231 = 500; in the pessimistic setting, 354 + 446 = 800. In steady state, Cornell needs to plan for an average quarantine + isolation capacity of 132 + 195 = 327 in the nominal setting; 509 + 796 = 1305 in the pessimistic setting.

Even if the assumptions of a given scenario hold, quarantine capacity is likely to be different from the average. If Cornell lacks the ability to flex quickly, then we must plan for additional capacity beyond the average reported above. We report the 90% quantile of the relevant quantities in Table 14 below.

[7] In Phase 3, the same initial prevalence was used across all simulations, even though the final prevalence of infectious & free differs across optimistic / nominal / pessimistic for Phases 1 and 2. This value does not affect the steady state numbers significantly as only simulation results from after the first 4 weeks of campus operation are used.

Table 14: Summary of the 90% quantiles of isolations and quarantines during the 14-day self-quarantine period, move-in weekend and 18 days afterwards, and in steady state, under three parameter settings (optimistic / nominal / pessimistic). Quarantine cases include those identified through contact tracing. Isolation cases include those identified through gateway testing and regular screening (including both true positives and false positives) and those individuals who self report.

	90% Quantile of Student Isolations			90% Quantile of Student Quarantines in On-Campus Dorms (and fraternities and sororities)			90% Quantile of Student Quarantines in Off-Campus Housing (excluding fraternities/sororities, including on-campus non-dorm)		
Optimistic / Nominal / Pessimistic	Opt	Nom	Pess	Opt	Nom	Pess	Opt	Nom	Pess
Phase 1 (14-day mandatory self-quarantine period)	91 (includes 76 due to positives in gateway testing)	118 (includes 100 due to positives in gateway testing)	150 (includes 124 due to positives in gateway testing)	N/A	N/A	N/A	36	84	162
Phase 2 (move-in weekend + 18 days after)	254 (includes 95 due to positives in gateway testing, 88 false positives in screening)	302 (includes 95 due to positives in gateway testing, 88 false positives in screening)	417 (includes 95 due to positives in gateway testing, 88 false positives in screening)	114 (includes 90 due to contact tracing from false positives)	264 (includes 180 due to contact tracing from false positives)	532 (includes 271 due to contact tracing from false positives)	241 (includes 187 due to contact tracing from false positives)	565 (includes 373 due to contact tracing from false positives)	1100 (includes 560 due to contact tracing from false positives)
Phase 3 (steady state)[8]	93 (includes 69 false positives)	173 (includes 69 false positives)	713 (includes 69 false positives)	80 (includes 70 due to contact tracing from false positives)	244 (includes 140 due to contact tracing from false positives)	1082 (includes 210 due to contact tracing from false positives)	158 (includes 145 due to contact tracing from false positives)	425 (includes 290 due to contact tracing from false positives)	1477 (includes 435 due to contact tracing from false positives)

[8] In Phase 3, the same initial prevalence was used across all simulations, even though the final prevalence of infectious & free differs across optimistic / nominal / pessimistic for Phases 1 and 2. This value does not affect the steady state numbers significantly as only simulation results from after the first 4 weeks of campus operation are used.