An achievable threshold isolation rate can still stop this pandemic

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Roger Ison
Miximum Diagnostics LLC
Loveland, Colorado
roger@miximum.info

Roger Ison is a Ph.D. computer scientist and computational modeler.

Introduction

China claims to have had no newly diagnosed, locally generated coronavirus cases for two consecutive days. Some observers assert this can't be possible, and certainly Chinese surveillance can't be perfect. Not every person who feels sick will report in. Nevertheless, it is feasible to achieve this sort of result in a country even after it has experienced a major outbreak like what occurred in Hubei Province.

Epidemic modeling shows that this may still be achievable in the United States.

Features of the model

This prediction is based on a model with the following features:

- SIR-type model with multiple outbreak centers that communicate by travel among them.
- The model runs accumulating numerical cycles, rather than integrating differential equations. Assumed cycle time is 1 week.
- Individual super-spreaders and transmission incidents modeled by sampling a log-normal distribution, rather than a single R0 rate.
- Herd immunity.
- Large population base (10m per outbreak center).
- Model allows changing the naïve R0 number as it proceeds, to represent the effect of self-isolation policies, which can also subsequently be relaxed. "Naïve" means that R0 is the mean rate of the log-normal disease spread distribution, before accounting for the presumed immunity of recovered individuals.
- The model can impose global quarantine on travel among outbreak centers, and then relax it later to see the effect on outcome.
- The model is stochastic because of the log-normal spread rate distribution.
- When modeling a pandemic (multiple, communicating outbreak centers), the model generates a range of travel probabilities between the centers, which governs how much travel actually occurs. Centers that are "farther apart" experience less travel.

For technical readers, here is an example to illustrate the super-spreader distribution:

```
Desired generated distribution mean R0 = 2.50 with underlying generator dispersion = 0.80
  underlying log-rate for generator = 0.596290731874155
It's stochastic, but for one generated, log-normal example with 100,000 incidents:
  mean spread rate =    2.4946721
  median spread rate =  1.8158659
  std deviation of spread rate distribution =  2.3444326
  spread rate range = [0.063 .. 47.877]
  80% of transmissions are generated by the top 51.7% of spreaders
```

The model's Python code can be downloaded here: https://github.com/redantison/PandemicSimulator

It is still possible to extinguish this pandemic

We are presently at roughly cycle 8 of the exponential growth process. The initial naïve R0, without imposing isolation and quarantine policies, is assumed to be 2.5. On the cycle when self-isolation policy is first imposed, the naïve R0 falls to a level that can be set as a parameter of the simulation. Likewise a global travel quarantine can be imposed at a specified cycle.

Depending on the R0 that is achieved by self-isolation, and when a global travel quarantine is imposed, the pandemic will either decline into a long behavior of waves until herd immunity mostly shuts it down; or, it will subside sufficiently that after a time, self-isolation and quarantine can be released without restarting the epidemic. There is a threshold where this works. If self-isolation reduces R0 to about 0.4 for two to three months, and travel quarantine prevents the epidemic centers from restarting each other, the pandemic will extinguish. If R0 is reduced less, to 0.5 or 0.6, it might not work; or controls will have to be maintained longer.

The point is: if the threshold rate is achieved, the pandemic will extinguish in a few months. The cost of achieving that is much less than the cost of dragging it out for 18 months to two years, which is the likely outcome of present Federal and Colorado policies.

"Early draconian" policy

It is very difficult to maintain even sloppy controls for a long time. People won't tolerate it. However, stringent controls for a limited time might be achievable if the purpose and goal are messaged clearly and consistently, and enforced at least socially.

I call this policy "Early draconian". I believe it's still feasible, although not at every national population center. But in many places, including Colorado, outbreaks are still at an early stage. Although the outcome is not entirely predictable, we can learn from multiple runs of the model what is likely to happen. To give technically informed readers an idea of what this looks like, consider a pandemic consisting of outbreaks with the following characteristics:

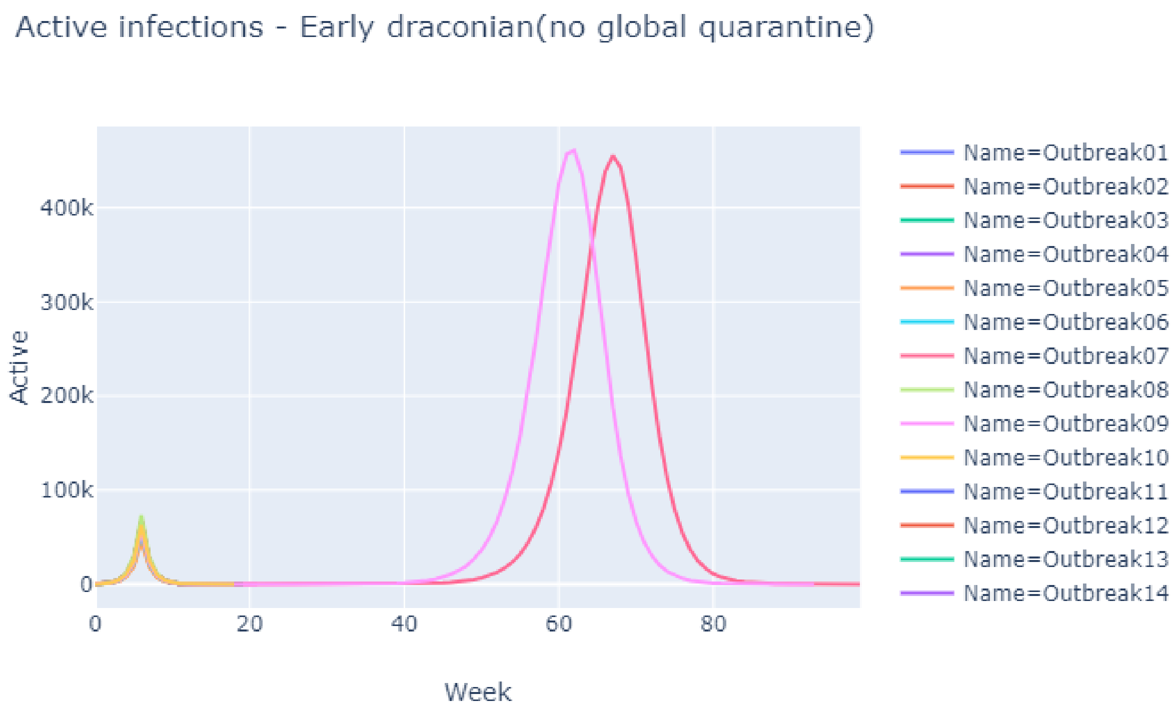
- 10m population per outbreak center
- Model includes herd immunity
- Infection cycle time 1 week
- Super-spreader log-normal distribution initially has a mean of 2.5 and dispersion of 0.80 (see below for what this means in practice)
- At cycle 7, very strict self-isolation is imposed to reduce R0 to 0.40. There may still be transmissions among co-domiciled individuals, but broadly the rate is suppressed.
- At cycle 20, restrictions are relaxed so R0 rises to 1.4. If the pandemic has not been extinguished, it would restart since the spread rate is now greater than 1.0.

So we're talking about stringent isolation for 20 – 7 = 13 weeks, about three months. According to this model, 8 weeks is not enough to avoid re-emergence, although some relaxation after 8 weeks might be tolerable.

Outbreaks considered in isolation

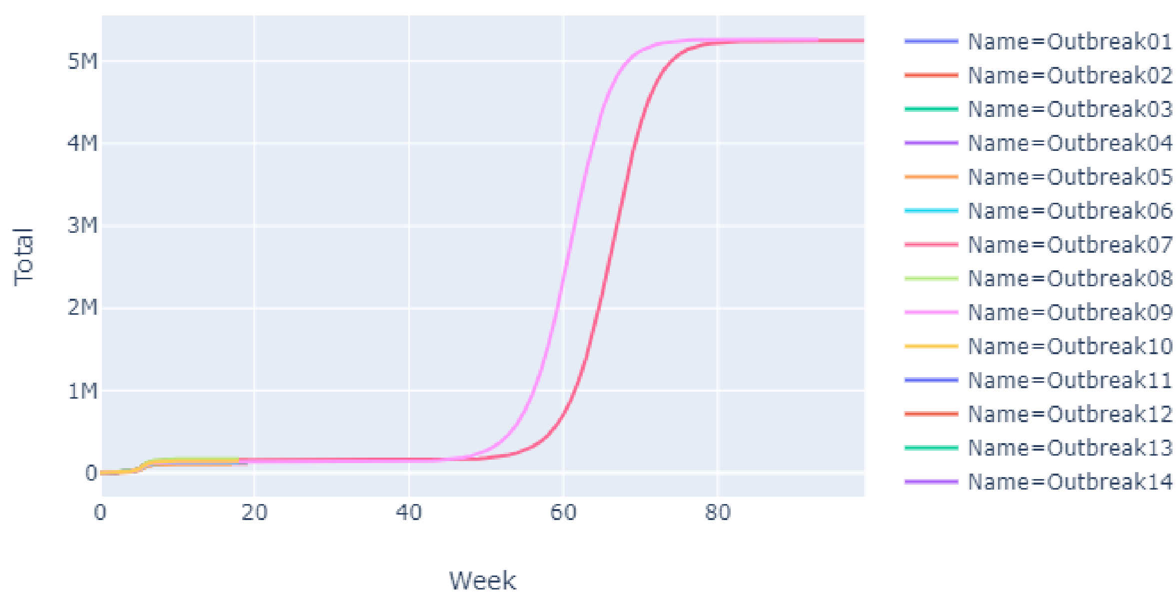
If we simulate 20 outbreaks *considered in isolation*, 18 of them die out; two restart when restrictions are relaxed at cycle 20. In the real world, of course, we would see this starting to happen and re-impose restrictions in the centers that re-start. But 90% of outbreaks are fully extinguished. Except for the two that restarted, cumulative infections are held to less than 160,000 per 10m people.

In the following three figures, each line traces the history of one isolated outbreak. Seeing 20 of these gives an idea of the range of behaviors. Only two progressed to a full-blown collapse after restrictions are relaxed. For the outbreaks that truly extinguished, total cases and total deaths remain remarkably low.

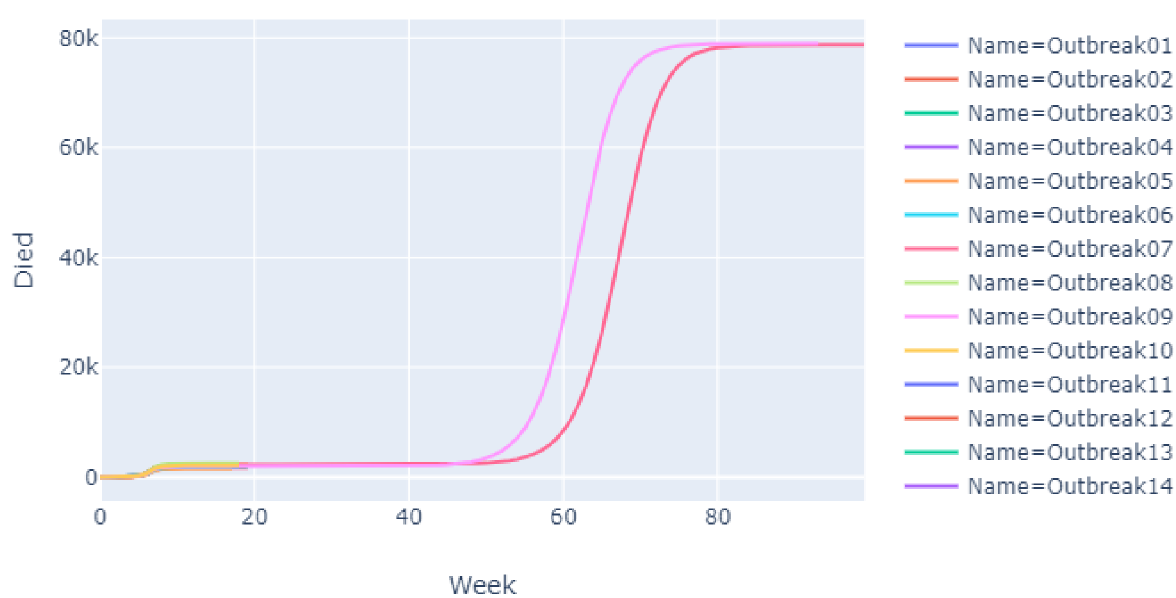


(There really are 20 lines here in different colors; the Figure's legend only shows through "Outbreak14" due to an artifact of how it was captured. An outbreak's line ends if it has self-extinguished.)

Cumulative infections - Early draconian(no global quarantine)



Cumulative deaths - Early draconian(no global quarantine)



Again, these results are stochastic because the assumed transmission distribution is log-normal. They'll be a bit different each time the simulation runs.

Pandemic outbreaks

Now we can consider a pandemic, which is properly understood as multiple outbreaks that communicate by individuals traveling between them. In this model, I've assumed that without a global quarantine, the probability of individuals traveling between outbreak centers is an exponentially declining function of the distance between them.

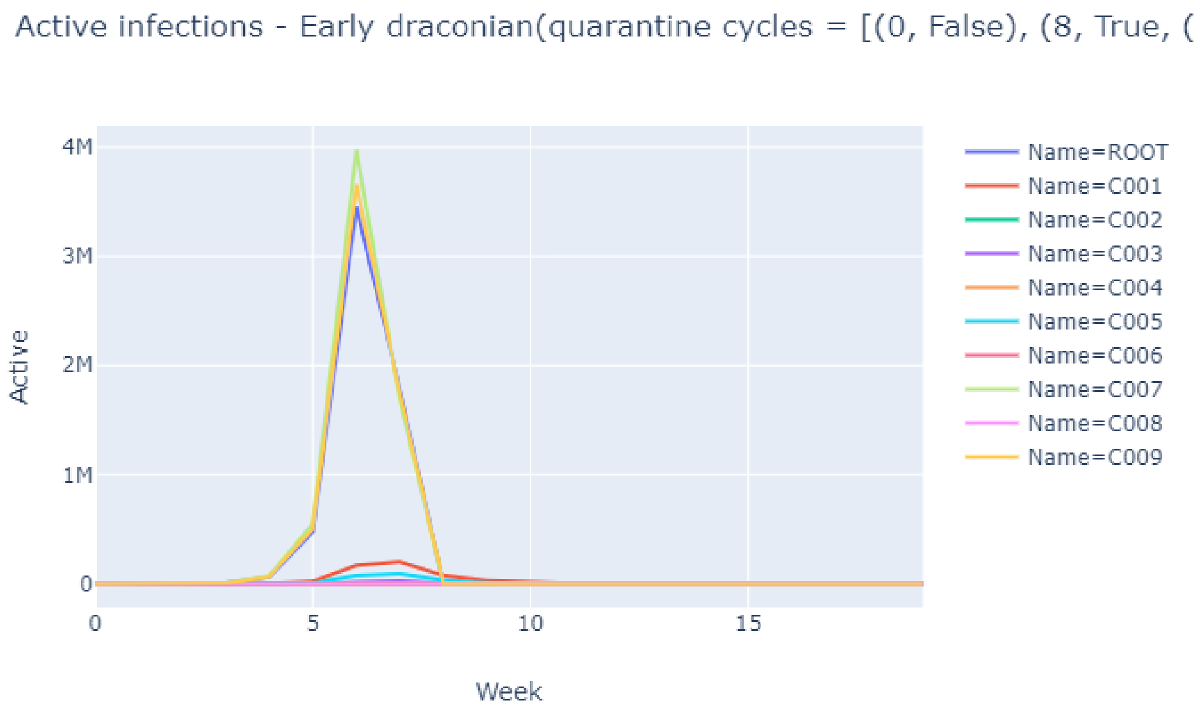
It turns out that the details of travel probability are not too important, because even a few travelers will ignite outbreaks in previously uncontaminated population centers. The exponential growth of the outbreaks dominates over the probability of travel.

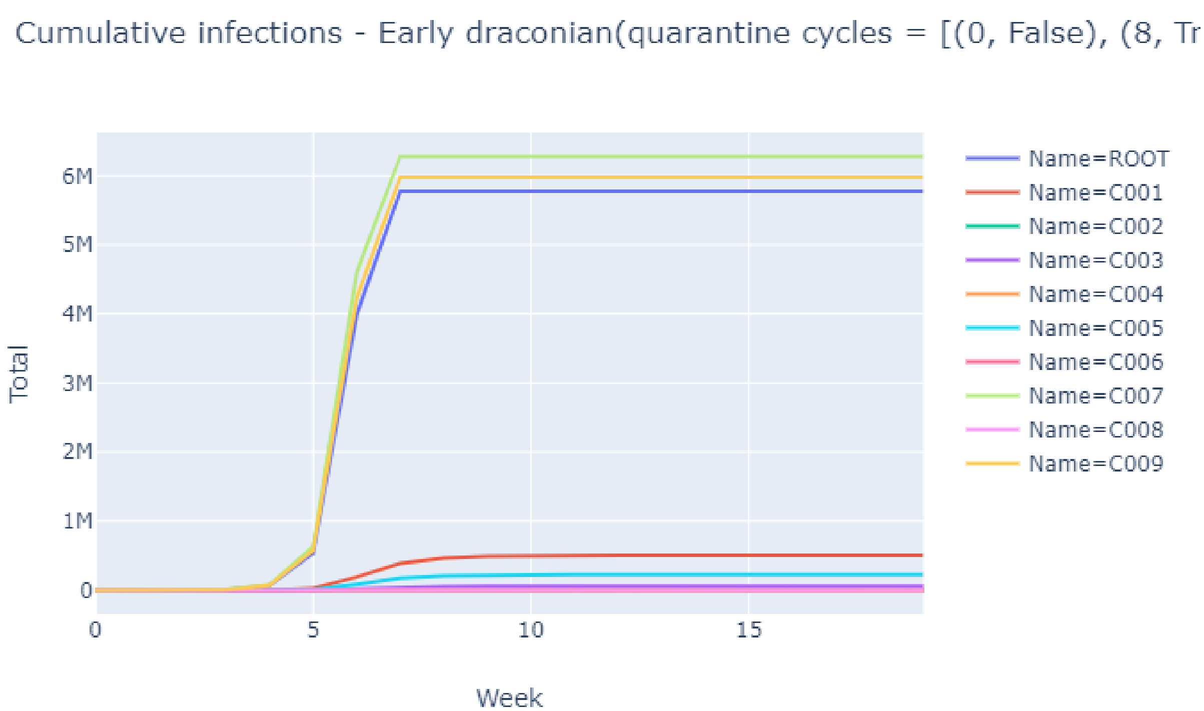
So the simulator lays out nine additional centers randomly over a geographic area, with travel between them controlled by their relative distances. The infection begins at a root population center in the middle of the "map", and spreads to other centers. Outbreak growth is somewhat accelerated by visitors: infected visitors add to the spread in a cycle, and uninfected visitors may become infected where they visit.

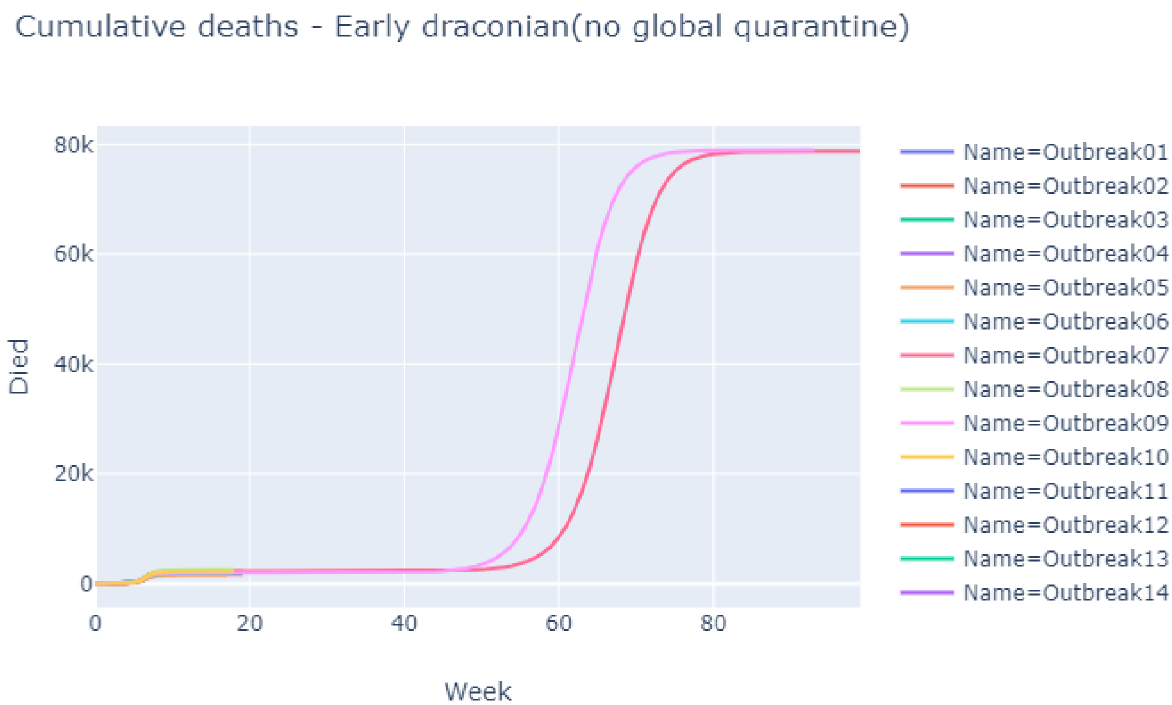
```
Run at  2020-03-21 19:20:00
Early draconian
  10 million population
  Infection cycle time 1 weeks
  List of naive R0 values by starting cycle number:  [(0, 2.5), (7, 0.4), (20, 1.4)]
  Standard deviation of the generated log-normal R0 distribution ~ 2.36
  Standard deviation of the underlying Gaussian distribution is 0.80
  Death rate 1.50%
  Herd immunity effect included
```

On cycle 8, a global travel quarantine is imposed, which is kept in place until being released in cycle 20. The individual outbreak parameters are exactly as discussed above, including imposition and release of self-isolation policies.

In the following plots, each line represents the trajectory of one of the 10 outbreak centers. Now what we see is that three outbreaks ran to burnout because they were already advanced when isolation was imposed. But the rest, which were not so far advanced because they started later due to travel, are well controlled at about 500,000 total infections per 10m population.


Active infections - Early draconian(quarantine cycles = [(0, False), (8, True, (
Active
4M
3M
2M
1M
0
0
5
10
15
Week
Name=ROOT
Name=C001
Name=C002
Name=C003
Name=C004
Name=C005
Name=C006
Name=C007
Name=C008
Name=C009


Cumulative infections - Early draconian(quarantine cycles = [(0, False), (8, Tr
Total
6M
5M
4M
3M
2M
1M
0
0
5
10
15
Week
Name=ROOT
Name=C001
Name=C002
Name=C003
Name=C004
Name=C005
Name=C006
Name=C007
Name=C008
Name=C009



Conclusion

There is a range of possible outcomes here; these graphs represent just one run in a stochastic model.

But the important point is that the pandemic does not restart when controls are relaxed at cycle 20, after being in place for three months. That is what happens consistently in these pandemic simulation runs, and that outcome is dramatically better than what we will experience under current policies.

The Chinese are not making it up: even now, this pandemic really can be suppressed.

The alternatives are terrible:

- A pandemic that is poorly suppressed and continues for at least a year, easily 18 months or more absent a vaccine or other medical breakthrough,
- Or, a pandemic that runs to burnout very fast, repeating the experiences of Hubei and Italy experiences all over the United States.