Ohio Redistricting 2023: the path to constitutionality

My name is Geoffrey M. Wise, and I have been a resident of Ohio since 1999. I currently reside in Wyoming, a northern suburb of Cincinnati, where I am a Ph.D. chemical engineer for a consumer products company. I have no formal training in political science, but I have great passion for bringing quantitative solutions to difficult problems in American representative democracy. I have published a paper on the political challenges to Electoral College reform in the academic journal *Statistics, Politics and Policy* (see https://doi.org/10.1515/spp-2021-0029), and I have written, with the guidance of a frequent gerrymandering expert witness / mathematics professor, two papers on neutral-map seat expectations in single-member districting plans. The first of these papers, about to be submitted to a leading political science journal, estimates the responsiveness and geography bias in 2021-22 U.S. Congressional redistricting from an analysis of the 22 most populous states. The second paper, not yet submitted, examines the role of Ohio's no-split rules on its seat expectations for legislative and Congressional redistricting.

The objective of this document is to guide the Ohio Redistricting Commission (ORC) toward constitutional legislative maps prior to any 2023 mapdrawing. To review, these maps must be redrawn in 2023 because the current maps have been declared unconstitutional in OSC-2021-1193 https://www.supremecourt.ohio.gov/clerk/ecms/#/caseinfo/2021/1193 by the Ohio Supreme Court, which retains exclusive redistricting jurisdiction per Ohio Constitution Article XI.8, consistent with the recent U.S. Supreme Court *Harper v. Moore* decision. In OSC-2021-1193, the mapmakers were defended by lawyer Philip Strach, who asserted that the majority party started from maps drawn without partisan intent, then moved toward proportionality. This "Strach method" of satisfying Article XI.6's partisan fairness language was favored by the three dissenting judges, but rejected as insufficient by four justices, including Chief Justice O'Connor.

Now that Justice O'Connor has retired and Justice Deters has been appointed by the governor to fill the Court's seventh seat, the ORC should anticipate that the Strach method will find favor with the 2023 Court. On the contrary, despite the change in Court makeup, we should NOT anticipate constitutionality for a map that delivers MORE expected seats for the majority party than neutral drawing. Such a map would be a deliberate step in the wrong direction, counter to the intent of the Article XI.6 "shall attempt" and "no … plan shall be drawn primarily to favor" language.

Therefore, it is critical to determine the Republican and Democratic seat expectations for a neutrally drawn map of compact districts; that is, following all technical requirements in Article XI's sections 2, 3, 4, 5, and 7 but uninformed by Ohio's spatial distribution of partisan voters. Armed with this determination, we can then classify maps into those that step toward proportionality and those that step away, with a clear constitutional mandate to reject the latter. But to my knowledge, this neutral-map calculation has not yet appeared in the voluminous docket of OSC-2021-1193, despite the considerable expert witness testimony therein. Let us now review the OSC-2021-1193 documents that come closest to providing an estimation of the neutral-map standard.

The transcript of the morning September 9th, 2021 ORC hearing includes an assertion by Sen. Huffman's mapmaker Ray DiRossi that partisan data was not used in the creation of the Statehouse map he presented that day, but a transcript of his later deposition reveals a different story, and a quick analysis reveals that this map falls on the unconstitutional side of the neutral standard, with obvious choices made to increase Republican seat expectations. (This can be verified using the files provided with this submission.) Secondly, in a September 14th, 2021 hearing, University of Cincinnati Professor David Niven asserted that the geography bias favoring the Republicans (due to high spatial clustering of Democratic voters) was usually about three percent, but he did not present a specific analysis for Ohio, nor did he include an estimate of Ohio's responsiveness for a 99-seat map that would be necessary to compute a neutral-map expectation. Auditor Keith Faber later quoted a range of three to five percent. Thirdly, in his expert testimony for the Relators, Professor Kosuke Imai did present the partisan seat expectations for a number of computer-drawn maps, but his mapmaking algorithm leveraged partisan data to drive the results toward maps more favorable to the Democrats than the neutral standard. And finally, expert witnesses Michael Barber and Sean Trende for the Respondents did show that Ohio's spatial clustering of Democrats result in less-than-proportional Democratic representation for neutrally drawn maps, but their analysis stopped well short of computing the statewide expectations for neutrally drawn maps.

In sum, neither side in OSC-2021-1193 presented a rigorous neutral-map analysis, not only because that result falls in the chasm between the number of seats each side hoped to win in the court case, but also due to the difficulty in respecting Ohio's many "no-split" requirements in performing the necessary computations. I am providing these computations as an interested Ohio citizen, without any payment or guidance from either side of the OSC-2021-1193 case, so that Ohio can move on from the destructive dysfunctionality of its redistricting impasse.

## ESTIMATION OF NEUTRAL-MAP EXPECTATIONS FOR STATEHOUSE MAPS

The OSC-2021-1193 litigation included differing opinions not only on the partisan fairness goal itself, but on how to incorporate recent election data into the assessment of partisan fairness, due to the lack of clarity in Article XI.6B: "The statewide proportion of districts whose voters, based on statewide state and federal partisan general election results during the last ten years, favor each political party shall correspond closely to the statewide preferences of the voters of Ohio." Do we sum up the vote totals across these elections, or take the average of each election's two-party percentages? Should recent election results be weighted more heavily? What do we do when spatial distribution of votes is not readily available for 2012 and 2014 elections? And now that the ORC's majority has chosen a path leading to a 2023 re-draw, are 2022 results now relevant?

When the metric of fairness is the disparity in seat expectations relative to a strict proportionality, that disparity depends on what value is selected for the representative statewide two-party vote split. The higher the selected value, the greater the apparent disproportionality. This occurs because Ohio's natural responsiveness R is greater than unity; a party can expect to pick up more than 1% of the seats for every 1% gain in vote share. In this situation, we can expect the majority and minority parties to

selectively interpret Article XI.6B in opposite ways, to minimize or maximize the appearance of disproportionality, respectively. And indeed, OSC-2021-1193 expert affidavits speak to the battle over which statewide average to use.

As we shall see below, this is much less problematic for the estimation of the departure from neutral-map expectations, which faithfully track a state's responsiveness as statewide votes shift left or right. Of course, key to proper evaluation of seat expectations is properly accounting for the uncertainty in outcome of competitive elections. Otherwise, we are back to the absurdity of calling a 50.1 / 49.9 district a red district and a 49.9 / 50.1 district a blue district, when either of those districts might be considered "flipped" by simply making a small change in how we estimate the statewide vote. In reality, these districts are close to toss-ups, while a 52/48 district is more likely (but not guaranteed) to be won by the first party. A rigorous analysis accounts for the spectrum from a partisan stronghold to a tossup district in a smooth, consistent manner.

Following common practice in the political science literature [see e.g. A. Gelman and G. King, ''A Unified Method of Evaluating Electoral Systems and Redistricting Plans.'' American Journal of Political Science 38: 514–54 (1994)], I account for this uncertainty by modeling each district election's two-party vote outcome as normally distributed with a standard deviation or uncertainty U. A commonly used value of U is 4%, (see Nagle and Ramsay, Election Law Journal 20,1 (2021), DOI: 10.1089/elj.2020.0674, "On Measuring Two-Party Partisan Bias in Unbalanced States" ) so I will show seat expectations for U values of 3% to 5% to show the lack of sensitivity to this parameter.

I will provide three different bases of computing neutral-map expectations that yield similar results:

1) Back-of-the-envelope
2) Computer-drawn, partisan-blind
3) Human-drawn, partisan-blind

The back-of-the-envelope method estimates the seat split based on the statewide vote split, the apparent votes-to-seats responsiveness R for a 99-seat Ohio map, and a reasonable value for the geography bias induced by stronger clustering of urban Democratic voters. Alternatively, partisan-blind computer drawing fuses voting precincts into compact districts conforming to Article XI rules. Unlike Prof. Imai's ensemble analysis, this is truly a partisan-blind analysis, in that precinct-level population data is the only demographic information used to draw districts. For the human-drawn analysis, I start from a map drawn from Pranav Padmanabhan, the winner of Fair Districts Ohio's 2021 mapmaking contest, where the contestant's stated goal was to minimize school district splits, without using any partisan data.

The details of these computations are relegated to the Appendix. For each of these methods, I report results for several assumed values of the statewide vote. I do so because I cannot predict the exact statewide vote split that will win favor with the 2023 Ohio Supreme Court. Any reasonable averaging of 2014 – 2022 statewide election results should fall within the range of the first column in the below table, or close enough for a linear extrapolation.

| TABLE 1: Neutral-map GOP seat fraction expectation for 99-seat Ohio legislature | | | | | |
|---|---|---|---|---|---|
| | R = 2.1, bias = 0.05 | U = 0.03 | U = 0.05 | U = 0.03 | U = 0.05 |
| **Statewide GOP/Dem vote** | **Back-of-envelope** | **Computer-drawn** | | **Human-drawn** | |
| **54 / 46** | 0.634 (63 seats) | 0.640 | 0.638 | 0.642 | 0.638 |
| **55 / 45** | 0.655 (65 seats) | 0.661 | 0.657 | 0.662 | 0.658 |
| **56 / 44** | 0.676 (67 seats) | 0.681 | 0.677 | 0.682 | 0.678 |

The Democratic clustering in Ohio and other midwestern states tends to run higher than the national average; hence I use the high end of the seats-bias values stated in 2021 ORC hearings for the back-of-the-envelope estimations. See the Appendix for a more detailed discussion on this point.

EXAMPLE NEUTRAL MAP

To give the ORC a starting point, this packet includes a neutral map in two formats: as a 2020 Census block assignment file and as a 2020 precinct assignment file. This map starts with the Huffman / diRossi 9/9/21 map, making minimal adjustments to improve compactness while achieving neutral seat expectations in line with the above table. Specifically, I reconfigured Cuyahoga, Hamilton, Lorain*, Lucas+Wood and Montgomery. The below chart compares this example map's votes-to-seats curve to the computer-drawn ensemble average at a modeled district election uncertainty of U = 4%.

| | **Expected GOP seats out of 99** | |
|---|---|---|
| **Statewide GOP / Dem lean** | **Example neutral map** | **Ensemble average** |
| R/D = 54/46 | 63.1 seats | 63.3 seats |
| R/D = 55/45 | 65.2 seats | 65.3 seats |
| R/D = 56/44 | 67.2 seats | 67.2 seats |

Once the ORC decides how far to step toward proportionality, they can adjust key counties in this example map as needed to achieve the desired partisan seat split. An analysis of my computer-drawn maps indicates that Hamilton, Montgomery, Summit, Lucas+Wood and Lorain are most amenable for compact redistricting to fine-tune the seat expectations. To minimally follow the Strach method, the ORC could simply reconfigure Summit County and/or Franklin County to increase Democratic seat expectations relative to my example neutral map. To further cement this point, I include a second block assignment file where key counties are left blank, awaiting the ORC's explicit articulation of their guiding partisan fairness standard.

This submission packet includes the raw python code and data files for reproducing my work. Anyone who wishes to compare a proposed map's seat expectations to the values reported in the above table can do so in a few minutes using an ordinary laptop computer.

The remainder of this document provides the methodology behind these calculations, followed by guidance for estimating neutral-map expectations for the Ohio Senate.

*To relieve population constraints in Lorain + Huron, the portion of Bellevue in Huron County was moved out of the Huron + Lorain district to join the district which contains Bellevue's Erie piece. This technically creates a Huron split but reduces the number of splits endured by Bellevue. Other than this minor change, my example neutral map splits the same counties as the 9/9/21 Huffman map.

## APPENDIX: CALCULATION DETAILS

BACK OF THE ENVELOPE method

Political-science academics describe the seat expectations for a map as a "votes-to-seats curve" which provides an estimate for the number of seats each party can expect for a statewide vote in a range that encompasses statewide two-party vote shares for recent elections. As described in J. F. Nagle and A. Ramsay, "On Measuring Two-Party Bias in Unbalanced States", Election Law Journal volume 20, number 1, 2021, DOI: 10.1089/elj.2020.0674, two numbers capture the essence of this translation from votes to seats:

1) The expected seat split at the most likely statewide vote split
2) The responsiveness (slope) of the votes-to-seats curve at that vote split

For competitive unbalanced states like Ohio, the recent election data set includes two-party vote splits very close to 50-50. In these states, we can describe the map's behavior using the responsiveness R and the "seats bias" SB, where SB is the additional fraction of seats that the Republican party can expect at a 50-50 statewide vote. For human-drawn maps, the value of SB can be manipulated to favor one party, but a nonzero SB is often found in neutral maps of U.S. states because Democrats tend to be more highly clustered; see e.g. Jonathan Rodden's 2019 book Why Cities Lose for details. When Prof. Niven was stating a geography bias of about three percent in his 9/14/2021 testimony, he was quoting an approximate empirically observed SB value for neutrally drawn maps. In a later redistricting hearing, Auditor Faber stated a value of three to five percent. The legal counsel for the Auditor's office declined to give me a source for that statement, but it is consistent with my estimation of 4% from a recent analysis of the 22 most populous states' 2021 neutral-map Congressional expectations. As noted by Rodden, the prevalence of modest cities in Rust Belt states tends to increase SB in these states relative to a nationwide average SB, as these towns reduce the "redness" of the rural background, increasing the votes-to-seats efficiency of Republican-controlled areas.

If SB is known or can be reasonably estimated, we can compute the expected fraction of Republican seats for any reasonable competitive statewide vote once we have estimated the responsiveness R:

$$\text{seats fraction} = 0.5 + SB + R * (\text{vote fraction} - 0.5) \qquad \text{Equation 1}$$

There is no universal value for R, but it can be estimated by noting how many more seats each party will pick up for a small uniform shift in statewide vote. States that are highly segregated into Republican and Democratic strongholds will have low responsiveness while states with small-scale partisan heterogeneity will have higher values, with the exact value of R depending on the degree of mixing relative to the district population size. For example, Ohio's R is about two for a 99-seat map of legislative districts and close to three for a 15-seat map of Congressional districts.

R can be estimated for both individual human-drawn maps and ensembles of computer-drawn maps. Below, I present computations of R for a number of Ohio legislative maps at a statewide vote of 54-46 GOP-Dem to show that the R value will tend to fall in a narrow range even for maps that are highly manipulated for partisan intent.

| Map | R value |
|---|---|
| 9/3/21 Sykes | 2.16 |
| 9/8/21 Padmanabhan | 1.97 |
| 9/9/21 Huffman / DiRossi | 2.05 |
| 9/15/21 Huffman | 1.90 |
| 2/24/22 enacted | 2.22 |
| Neutral drawing, respecting Article XI rules | 2.10 |
| Neutral drawing, ignoring Article XI.3D rules | 2.14 |

The 9/3/21 map proposed by Democratic Ohio state senator Vernon Sykes and the 2/24/22 enacted map were drawn with a specific intent of creating a large number of light blue or toss-up districts; hence their higher R values. If we take the natural R value for Ohio 99-seat maps as falling between 1.9 and 2.2, we arrive at the following GOP seat expectations using a seats bias of SB = 0.05:

| Statewide GOP/Dem | R = 1.9 | R = 2.2 |
|---|---|---|
| 54 / 46 | 0.626 (62.0 seats) | 0.638 (63.1 seats) |
| 55 / 45 | 0.645 (63.9 seats) | 0.660 (65.3 seats) |
| 56 / 44 | 0.664 (65.7 seats) | 0.682 (67.5 seats) |

COMPUTER DRAWING method

To arrive at the expected results for code-driven mapmaking, we must define the range of possible maps, then run the code to appropriately and efficiently sample that space, and finally convert the breadth of the generated solutions into a neutral map expectation. As noted in both Ray DiRossi's 9/9/2021 testimony and the expert affidavit of Prof. Kosuke Imai, the restrictions on splitting municipalities and counties in Ohio Constitution Article XI.3 and XI.4 severely constrain the legal possibilities for 99-seat Statehouse maps for which contiguous triplets of Statehouse districts can form 33 legal Senate districts. This is particularly true in northeast Ohio, containing several contiguous counties with populations exceeding a full legislative district, making it difficult to simultaneously satisfy the Statehouse and Senate splitting restrictions. In the course of the 2021-2022 redistricting cycle, only two legal possibilities for northeast Ohio were seriously considered.

In the simpler scheme, used in the September 2021 Huffman maps, the Cuyahoga remnant is paired with Geauga and Summit. This tricounty district plus ten Cuyahoga districts and four Summit districts form five triplets for Senate districts. The part of Geauga not in this tricounty district is then paired with Ashtabula and Lake to form another Senate triplet. Stark County supports a full Senate district plus a partial legislative district that is completed by counties further south. Trumbull and Portage are paired to create three legislative districts which nest to one Senate district.
This scheme leads to 18 legislative districts in the Cuyahoga-Summit-Geauga-Lake-Ashtabula region that average 104.0% of the mean district population, which is challenging but still presents flexibility in drawing districts that respect Article XI.3 constraints without splitting precincts.

An even more constrained scheme, used in the Feb. 2022 enacted plan, forms a triplet out of Trumbull, Ashtabula, and part of Geauga. The remaining part of Geauga forms a district with part of Portage and Summit, and this tricounty district is combined with full Summit and Portage legislative districts to form a Senate triplet. The rest of Summit supports a full Senate district. These pairings are not particularly constrained, but this cannot be said for the pairing of Cuyahoga with Lake to form twelve districts with an average district population of 124785, which is 104.7% of the average district population, very close to the 105% upper limit. In other words, the average district population in these twelve districts is only 361 people less than the maximum allowable 2020 Census district population. To maintain adherence to Article XI.3 requirements, this enacted plan contains multiple precinct splits in northeast Ohio and appears to have a number of visually noncompact districts. I therefore do not consider neutral-map drawing based on this second scheme.

Outside of northeast Ohio, mapmaking is relatively unconstrained, and as noted by several OSC-2021-1193 experts, can be described as isolated regions where Democrats can win (or at least compete for) seats, surrounded by counties that will form solidly Republican districts no matter how the counties are paired. Therefore, we can simplify our analysis by studying each of these blue-to-purple regions in isolation. In fact, Article XI.3.C rules require us to take this approach of first developing regional maps to accommodate the more populous counties and then fill in the map by piecing together smaller counties with splits as needed.

Aside from northeast Ohio, the only area that merits particular attention is the Dayton area. Dayton's Montgomery County adjoins multiple counties that exceed 125,000 persons; hence, care must be taken to respect all Article XI rules in pairing counties in this area. My approach is to create a number of 7-district regional plans that include four full Montgomery districts, a Montgomery partial paired with adjacent county populations, and two more districts that incorporate adjoining Greene and Clark populations. Unlike Prof. Imai, I consider all legal Montgomery County pairings, not just the one selected by the ORC majority. Once these seven districts are drawn, there is no value in expanding the regional map with additional districts, as those districts will be universally Republican strongholds, including the three full districts in Butler County. In other words, a regional map of seven Dayton-area districts can be drawn in isolation, with no influence on district boundaries in Hamilton County, Franklin County or northwest Ohio, the closest areas where blue or purple districts can be formed.

Other parts of Ohio are far less constrained. Toledo's Lucas County can easily be legally paired with Wood, Fulton or Ottawa. Lorain can be paired with either Erie or Huron. Hamilton can be cleanly divided into seven whole districts. Franklin can be divided into eleven whole districts or eleven districts plus a partial to be paired in one of multiple adjacent counties. Mahoning can be divided into two districts, with a small contribution from Columbiana if needed. In southeast Ohio, many county pairings are possible to incorporate the city of Athens into a legislative district with at most one split county, including the possibility of splitting Athens County.

I have included my code for neutral map drawing so that others can independently verify that it uses no partisan data; the only inputs are the populations, shapes and county assignments of each 2020 Census vtd. My regional drawing algorithm proceeds by "cake-cutting" each populous county to form the

requisite number of whole districts and remainder population to be paired with the nearest available county. The cake cuts are snapped to the nearest municipal boundaries to promote compact district shapes. Once each regional "cake" is cut into the requisite number of districts, they are checked for contiguity, population, and adherence to Article XI.3 municipality splitting rules; only legal regional maps are stored as districts lists of 2020 precincts. Because they do not affect partisan analysis, Ohio areas outside precinct boundaries are not assigned; it is assumed that mapmakers will assign them properly.

This process is repeated for multiple cake-cutting orientations and cake-cut starting points near the perimeter of the triggering populous county. I weigh the contribution of each regional map to the expected outcome in that region based on what fraction of the regional population is best centered in a district in that regional plan relative to all other legal compact plans computer-drawn for that region. In other words, in the spirit of the ORC soliciting public input on proposed maps, the weighting is equivalent to each inhabitant "voting" for the regional plan that best centers them in a district. The precinct lists and weighting for each of these regional plans are included in this submission packet. Each region will have anywhere from a handful to dozens of legal regional maps that count toward the overall regional expectations, and all of these regional plans are independent, leading to a staggering number of contemplated statewide legislative plans.

In sum, before we even consider the additional combinations possible via variations in how Hamilton and Franklin counties are partitioned, the above method effectively considers 130 trillion different constitutional legislative maps, far more then Prof. Imai's purported ensemble of 1000 independent 99-seat maps (see a later affidavit in the OSC-2021-1193 record for Sean Trende's allegation that many of these Imai maps were not independent). This is partly due to my ability to create isolated regional plans, but also because Prof. Imai restricted his analysis to maps that followed the same county-splitting scheme as the 9/15/21 Huffman plan. My simulations follow Huffman splitting in northeast Ohio, but in less constrained areas it considers the full range of practical county splits.

HUMAN-DRAWN MAP

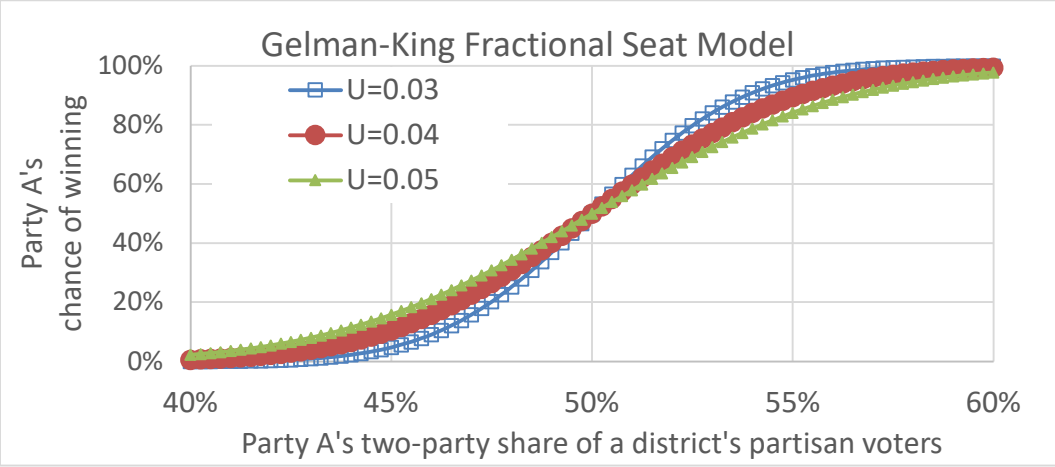
We cannot assume that humans will ignore partisan data in their map drawing, even if they assert that they are attempting a neutral draw. This is particularly true of mapmakers connected to a political party like Ray DiRossi, who had access to partisan data and motivation to favor his employer's interests. With ready access to partisan data, even ordinary citizens cannot be relied upon to put aside their political views in their mapmaking. I therefore hesitate to present any human-drawn map as "neutral", but I have personal knowledge of one former Ohio resident who attempted just that. For his submission to Fair Districts Ohio's citizen mapmaking contest, Pranav Padmanabhan (formerly of Franklin County, Ohio, moved to Colorado in 2023) drew a map, uninformed by partisan data, with the intent of keeping Ohio school districts together. This map was not submitted to the Ohio Redistricting Commission website, but was posted online at https://davesredistricting.org/maps#viewmap::580cc4db-445f-4a6a-a1e5-f78ce3a43bed on September 8th, 2021. Although this map does not strictly follow all of Article XI's no-split rules, I include it as an example of a neutrally drawn map to compare to the results obtained using the other two methods.

**METHODOLOGY OF CONVERTING VOTES TO SEATS**

As previously stated, Article XI.6B does not unambiguously define how one is to project a map's expected seat splits from recent statewide elections. My method is as follows:

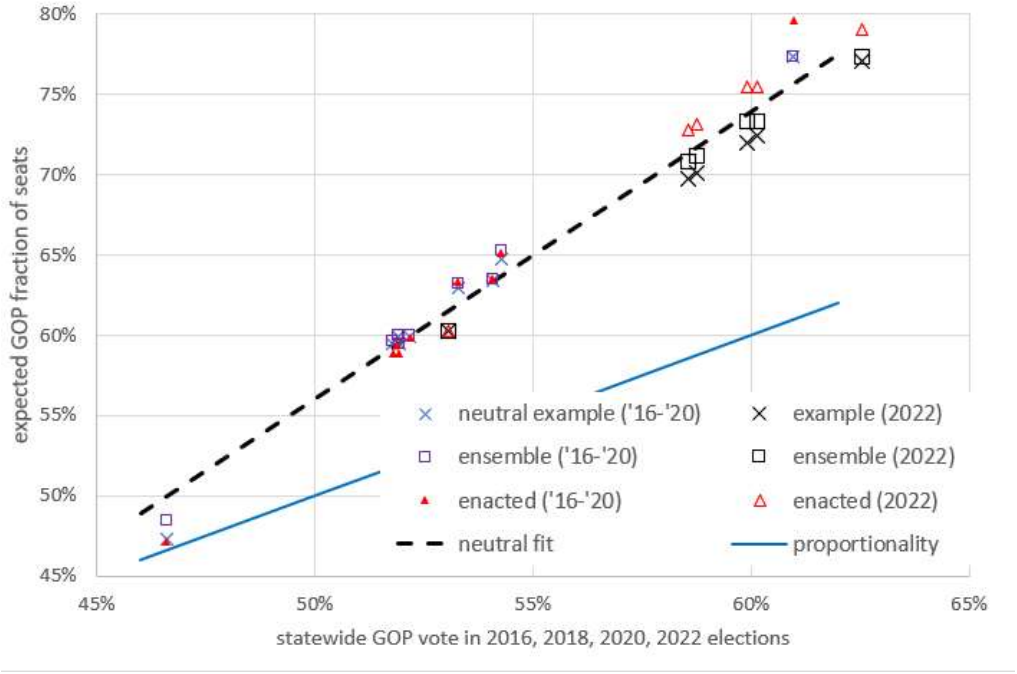
My starting point are the precinct-level results for every 2016 – 2022 statewide general election for U.S. President, U.S. Senate, Ohio governor, attorney general, secretary of state, auditor and treasurer, available from the Ohio Secretary of State's website. (As noted by OSC-2021-1193 expert witnesses, publicly available data is insufficient to join the 2014 precinct boundaries with election results.) When a proposed district is formed from whole precincts, a district's mean expected two-party vote share based on a given recent statewide election is computed by simply summing the votes from all precincts incorporated into that district. When a precinct is split by a district boundary, I model that precinct's ratio of Democratic to Republican votes as uniform within each precinct. A split precinct's partisan votes are allocated among districts in the same proportion as the estimated Citizen Voting Age Population in the 2020 Census blocks assigned to each district, where the ratio of CVAP (reported at the blockgroup level from the 2015-2019 American Community Survey) to total 2020 Census population is modeled as spatially uniform within each 2020 blockgroup. Up to this point, my approach is consistent with the methodology of the OSC-2021-1193 expert witnesses.

The net result is a mean expected two-party vote share for each district for each recent statewide election. As stated in the main section of this document, to properly account for the probability of upsets in competitive elections, the two-party vote share is modeled as normally distributed about this mean with a standard uncertainty U. A generally agreed-upon value of U in the political science literature is U = 4%, but U values of 3% or 5% are not uncommon [see A. Gelman and G. King, ''A Unified Method of Evaluating Electoral Systems and Redistricting Plans.'' American Journal of Political Science 38: 514–54 (1994) and pp. 58-60 of A.J. McGann et al, Gerrymandering in America, 1st edition. New York, NY, Cambridge University Press (2016)]. The main section presented results for U values of 3% to 5% to demonstrate insensitivity to this chosen parameter in a reasonable range. For reference, the below graph plots the seat expectation vs. mean two-party vote share for U = 3% - 5%. The Democratic (or Republican) seat expectation for the entire 99-seat map for a future election that resembles a recent statewide election is then simply the sum of the seat expectations for each of the 99 districts.



The next step is to synthesize the results from each recent statewide election into an overall projected result for a given map. The OSC-2021-1193 experts tended to report this as a single value, which wastes the richness of the recent election data's value in informing our near-future outlook. Instead, I take a data scientist's interpretation of XI.6B's "shall closely correspond" language, creating a linear correlation of expected seats to statewide vote. In the absence of more specific ORC guidance, I weigh each recent election equally in that linear regression. This linear regression allows a map's responsiveness to be measured directly from the statewide election data without resorting to counterfactual uniform swings. Furthermore, if there is uncertainty over the proper mean value of the future statewide vote – particularly in a state that is drifting in its partisan lean – the analysis is readily amenable to computing the seat expectations at any alternate statewide vote within the range covered by recent elections.

For additional clarification of the results presented in the main section's Table 1, below I plot this linear regression for my neutral-map seat expectations across the full set of 2016 – 2022 statewide elections, using a standard uncertainty U = 4%. This plot includes a regression for the neutral-map ensemble, which falls on top of a regression for the example neutral map supplied in this submission packet.

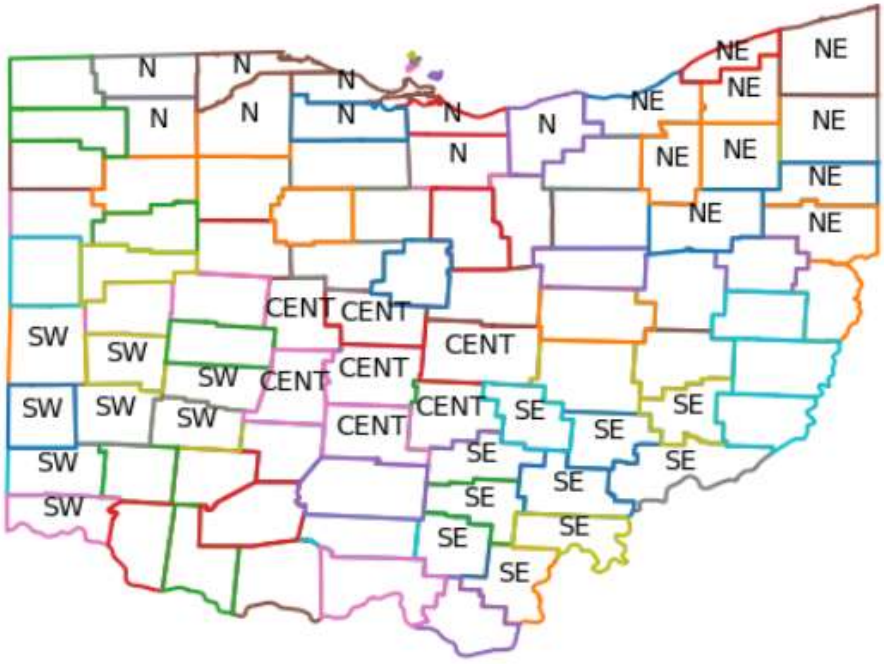



Three points are worth emphasizing here:

1) Although the regressions include the 2022 statewide election results, it is clear that the regressions would be very similar without them. In other words, neutral-map expectations are not significantly swayed by whether we include 2022 results in our seat expectation calculation.
2) The seat expectations for the example neutral map match very closely to the expectations from the ensemble of computer-drawn maps, whether we look at seat expectations from recent individual statewide elections or by regressing across these many elections.

3) The 2022 enacted legislative map is above (on the wrong side of) neutral expectations when the GOP performs strongly. Article XI.6 requires an attempt to move down toward proportionality.

The above is a statewide analysis of the Republican seat expectation. The ORC may be additionally interested in ensuring regional compliance to the Strach standard. To support such an endeavor, additional code blocks to regress regional seat expectations are included in this submission packet's seat expectations analysis code. The code takes advantage of the isolation of purple-to-blue areas; we can identify the subset of Ohio counties that could contribute population to compact legislative districts that are competitive or solidly Democratic. The below map divides these counties of interest into five regions. (For a map of compact districts, all other Ohio counties will contribute solely to solidly Republican districts; these other counties can be ignored in our analysis of seat expectations.)



**OHIO SENATE ANALYSIS**

The overwhelming majority of attention in Ohio legislative redistricting has been focused on the House map rather than the Senate map. This is understandable for two reasons. Firstly, the Senate map is derived from the House map, so a constitutional House map must come first. Secondly, it is generally accepted that Ohio's political geography is expected to deliver a supermajority of Republican seats; hence, there is little value in the Democrats fighting for a larger but still powerless minority of Senate seats. However, there was contention between the majority and minority members of the ORC on certain House → Senate nesting choices, particularly in Hamilton County. Therefore, below I provide some guidance on setting neutral-map expectations for the Ohio Senate.

As for the House analysis, the starting point is narrowing our focus to regions that can form Democratic or competitive districts. Let us review each of these areas individually:

**North region:** At most three Democratic seats, two that encompass Lucas County, and one that encompasses Lorain County. There is considerable flexibility in the House → Senate nesting for Lucas districts. For Lorain's Senate district, there is minor variation in partisan makeup based on the county paired with Lorain to complete Lorain's third legislative district.

**Northeast region:** This region supports nine Senate districts. In taking the same view of county splitting possibilities as for my House analysis, Trumbull and Portage are forcibly paired to form a full Senate district of fixed partisan voters. Lake, Ashtabula and a part of Geauga form another Senate district with very little possible variation in partisanship. The same can be said for the fully Stark district, which must include more than 90% of Stark, including the cities of Canton and Massillon. There is minor flexibility in the partisan makeup of the Senate district that incorporates all of Mahoning County, depending on how the rural legislative district south of Mahoning is drawn.
In contrast, there is significant flexibility in the partisan makeup of the five Senate districts that encompass Cuyahoga, Summit, and the piece of Geauga in the Cuyahoga-Summit-Geauga tricounty legislative district.

**Southwest region:** Hamilton County comprises seven whole legislative districts, resulting in two fully Hamilton Senate districts and a third Senate seat that incorporates the seventh Hamilton Statehouse seat. The partisan makeup to the east and north of Hamilton County ensures that this third Senate seat is controlled by Republicans, but there is considerable flexibility in how the two fully Hamilton Senate seats are formed, leading to either one or two likely Democratic seats. Similarly, Montgomery County's legislative seats can be combined in different ways to enhance or suppress the probability of a Democratic seat.

**Central region:** As in Hamilton, how the Statehouse seats are grouped into Senate seats has significant impact on the expected number of Democratic seats.

**Southeast region:** There are not enough Democrats to support a competitive Senate seat in this area with any legal compact districting scheme.

Summarizing the above, we can project that the Democrats will assuredly win a minimum of seven Senate districts when they are maximally packed, with the possibility of picking up three or four more seats from competitive districts. But alternate nesting schemes (particularly involving Lucas, Cuyahoga, Summit, Montgomery, Hamilton and Franklin counties) can increase their mean seat expectations by several seats relative to the most Republican-friendly nesting scheme. How do we estimate the neutral-map expectations?

One approach is to start from a constitutionally adopted legislative map, examining all possible legal sets of 33 triplets that can be formed. To my knowledge, the triplet nesting problem has not been generally solved [see e.g. S. Caldera, D. Deford, M. Duchin, S. Gutekunst & C. Nix (2020) Mathematics of Nested Districts: The Case of Alaska, Statistics and Public Policy, 7:1, 39-51, DOI: 10.1080/2330443X.2020.1774452], but the seat expectations of the ensemble of legitimate schemes in Ohio is computationally tractable due to the Senate nesting restrictions and the relative isolation of areas that can deliver Democratic seats. We could then define a quantitative criterion for rejecting schemes that do not meet Article XI.6C. Finally we could set the neutral-map standard as the mean seat expectation among the remaining schemes, perhaps with some weighting to favor schemes with higher compactness.

A far more practical approach is to implement a version of the noncooperative cake-cutting game; see e.g. W. Pegden, A. D. Procaccia and D. Yu, "A Partisan Districting Protocol with Provably Nonpartisan Outcomes", https://doi.org/10.48550/arXiv.1710.08781 . Starting from a legal legislative map, such as one adopted by an ORC majority, a "turn" consists of forming a Senate triplet from three legislative districts such that it is still possible to create a legal Senate map from remaining turns. The first turn is taken by the party that did not propose the legislative map, with a prescribed allocation of subsequent turns, such as strict alternation. The districting process ends when no more turns are needed to define the Senate map. This process could be performed by actual ORC members or by simulating both parties' optimal strategies.

A third approach would be to start from computer-drawn collections of regional legislative plans. For each regional plan, we could then select the House → Senate nesting that maximizes the compactness of the resulting Senate districts. For a compactness measure, I recommend following a variation of the relative proximity index from R. G. Fryer and R. T. Holden, "Measuring the Compactness of Political Districting", Working Paper 13456, http://www.nber.org/papers/w13456, October 2007. This measure seeks to minimize the sum of the squared distance of each inhabitant from their district's population centerpoint. We then weight each regional plan's most-compact nesting scheme contribution to the neutral-map seat expectation as we did for the regional legislative plans.

Upon direction from the ORC, I am willing to provide computational assistance to further any of the above methods of estimating neutral Senate map seat expectations.

**INPUT AND OUTPUT FILES**

INPUT DATA: All data sets used in this analysis were downloaded from the Redistricting Data Hub (RDH = redistrictingdatahub.org/state/ohio), which hosts redistricting data contributed by state governments, U.S. Census and academic groups such as the Harvard-based Voting and Election Science Team (VEST), as well as data sets synthesized by RDH via merging of data from these primary sources. RDH's primary source of Ohio election data is the Ohio Secretary of State's website: https://www.ohiosos.gov/elections/election-results-and-data/

The following RDH-housed files were used:

1) 2020 Census block populations and their assignment to 2016, 2018, 2020 and 2022 Ohio precincts [oh_gen_2022_prec_baf]
2) American Community Survey estimations of CVAP (citizen voting age population) by 2020 blockgroup (oh_cvap_2020_bg)
3) 2016, 2018, 2020, 2022 precinct-level November election results for statewide Ohio offices (U.S. President, U.S. Senate, Governor, Attorney General, Treasurer, Secretary of State and Auditor) joined to the shapes of those years' Ohio precincts* (oh_vest_16, oh_vest_18, oh_vest_20, oh_2022_gen_prec_st)
4) 2020 Census population data mapped onto 2020 vtd's (oh_pl2020_vtd)

RAW OUTPUT FILES:

To enable verification of my methodology, this submission includes several files that I generated to link these data pieces together:

a) 2020 Census block CVAP and partisans per 2016 - 2022 statewide election
b) 2016, 2018, 2020, 2022 statewide November election results re-aggregated to 2020 precincts
c) Each computer-drawn legislative district's list of 2020 precincts and ensemble weighting

PYTHON CODES:

- An "aggregation" code that creates a) from 1), 2), and 3) then creates b) from 1), 4), and a)
- A neutral drawing code that creates c) from 4)
- A "calc_expSeats" analysis code for calculating the expected seats from b) and c). This code also computes expected seats from a proposed plan's block assignment file. I downloaded these proposed BAF's from redistricting.ohio.gov/maps#view-maps (excepting the Padmanabhan map, which as previously noted was downloaded from Dave's Redistricting)

The "2023_FLFC_fileList" summarizes the content of each file in this packet. All python codes were run in a Jupyter notebook on a conventional laptop via a Docker Desktop virtual machine.

* Strictly following Article XI.6B would require including 2014 data, but as noted by multiple expert witnesses in OSC-2021-1193, the 2014 data is not readily available in a form conducive to spatial analysis.