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IN THE SUPREME COURT OF PENNSYLVANIA

No. 7 MM 2022

CAROL ANN CARTER *et al.*,
Petitioners,

v.

LEIGH M. CHAPMAN, *et al.*,
Respondents.

INTERVENOR-RESPONDENT GOVERNOR THOMAS W. WOLF'S EXCEPTIONS TO THE SPECIAL MASTER'S PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW AND INCORPORATED BRIEF IN SUPPORT THEREOF

On Review of the Special Master's Proposed Findings of Fact and Conclusions of Law, Nos. 464 M.D. 2021 and 465 M.D. 2021 (February 7, 2022)

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I. INTRODUCTION

Pursuant to this Court's Order dated February 2, 2022, Intervenor-Respondent Governor Tom Wolf (the "Governor") submits these exceptions to the Report of the Special Master, the Honorable Patricia A. McCullough. The Governor respectfully takes exception to the Special Master's (1) recommendation that this Court adopt HB 2146[1] as Pennsylvania's congressional district plan, as well as the proposed findings of fact and conclusions of law supporting that recommendation; and (2) proposed revision to the 2022 election calendar. *See* Report Containing Proposed Findings of Fact and Conclusions of Law Supporting Recommendation of Congressional Redistricting Plan and Proposed Revision to the 2022 Election Calendar/Schedule (Feb. 7, 2022) (the "Report").

As set out in more detail below, the Report's proposed findings of fact and conclusions of law reflect critical errors. Accordingly, Governor Wolf respectfully requests that the Court decline to accept the Special Master's recommendation and

[1] "HB 2146" is the proposed plan offered by the Speaker and Majority Leader of the Pennsylvania House of Representatives (the "House Republican Intervenor-Respondents") and the President Pro Tempore and Majority Leader of the Pennsylvania State Senate (the "Senate Republican Intervenor-Respondents) (collectively, the "Republican Legislative Intervenor-Respondents"). Although HB 2146 derived from a redistricting plan created by a citizen, Amanda Holt, it was altered during the legislative process. HB 2146 was first introduced in the General Assembly and referred to the State Government Committee on December 8, 2021, and then passed the House of Representatives on January 12, 2022. On January 24, 2022, the Senate gave HB 2416 third consideration and passed it. *See* Pennsylvania General Assembly, Bill Information – History, *House Bill 2146; Regular Session 2021-2022*, https://www.legis.state.pa.us/cfdocs/billInfo/bill_history.cfm?syear=2021&sind=0&body=H&type=B&bn=2146.

instead select the Governor's Plan, or, in the alternative, select or enact another plan that provides all Pennsylvanians with an equal opportunity to elect the representative of their choice. As to the Special Master's proposed revision to the 2022 election calendar, the Governor respectfully recommends that the Court modify certain election-calendar deadlines as specifically set forth in Respondents' Exceptions to the 2022 Election Calendar/Schedule, which is being filed concurrently with these Exceptions.

At the evidentiary hearing conducted by the Special Master, compelling evidence showed that the Governor's Plan was ideally suited to ensure "that the power of [each] vote in the selection of representatives [would] be equalized to the greatest degree possible with all other Pennsylvania citizens." *League of Women Voters v. Commonwealth*, 178 A.3d 737, 817 (Pa. 2018) ("*LWV I*"). Yet the Special Master recommended that this Court select (and treat as presumptively reasonable and legitimate) HB 2146, which Governor Wolf vetoed after determining that it is fundamentally unfair. HB 2146 demonstrably falls below the bulk of the other proposed maps at both (1) step one of the *LWV I* analysis, which measures adherence to the "neutral criteria" of compactness, contiguity, population deviation, and keeping together political subdivisions; and (2) step two of the *LWV I* analysis, which assesses whether a plan "prevent[s] dilution of an individual's vote" and gives "all voters … an equal opportunity to translate their

votes into representation." 178 A.3d at 804, 817. Under this Court's decision in *LWV I* and its other redistricting precedents, this Court should reject HB 2146 and select the Governor's Plan, which "comes closest to the constitutional standards in all pertinent respects." *Mellow v. Mitchell*, 607 A.2d 204, 218 (Pa. 1992).

II. BACKGROUND

On January 24, 2022, rather than passing an evenhanded map commanding bipartisan support, the General Assembly rammed through, along mostly partisan lines,[2] a map that fundamentally fails the test of fairness. *See* HB 2146, 2021-2022 Reg. Sess.[3] As the Governor made clear prior to final passage,[4] that map is unacceptable; he could not, in good conscience, sign it into law. Accordingly, on January 26, 2022, the Governor vetoed the General Assembly's bill for failing to

[2] The Pennsylvania Senate voted along party lines. *See* https://www.legis.state.pa.us/cfdocs/legis/RC/Public/rc_view_action2.cfm?sess_yr=2021&sess_ind=0&rc_body=S&rc_nbr=429. In the House of Representatives, all Democrats and two Republicans voted against HB 2146. *See* https://www.legis.state.pa.us/CFDOCS/Legis/RC/Public/rc_view_action2.cfm?sess_yr=2021&sess_ind=0&rc_body=H&rc_nbr=708.

[3] When the Senate State Government Committee initially passed HB 2146, the Senate Republicans issued a Press Release acknowledging that HB 2146 was not bipartisan and was being advanced merely as a means to an end. The Press Release stated that the Committee had "move[d] this bill through the legislative process to meet the deadlines set by the Department of State, in order to avoid delaying the primary election," but that "[b]ipartisan negotiations [we]re continuing in the hopes that a compromise can be reached." Press Release, *Congressional District Map Advances to the Senate* (Jan. 18, 2022), https://www.pasenategop.com/blog/congressional-district-map-advances-to-the-senate/.

[4] *See, e.g.*, Letter from Governor Tom Wolf to Speaker and Majority Leader of Pennsylvania House of Representatives (Dec. 28, 2021), https://www.governor.pa.gov/wp-content/uploads/2021/12/12.28.21-TWW-Cutler-Benninghoff-HB-2146-Final.pdf.

"deliver on the Pennsylvania Constitution's guarantee of free and equal elections."[5] Given these developments, it was clear that the executive and legislative branches had reached an impasse, and that the judiciary would need to adopt a new congressional districting plan.

On January 14, 2022, the Special Master ordered the parties (including those permitted to intervene, *see* Report at 12-13) to submit no more than two proposed 17-district congressional redistricting plans and a supporting brief and/or expert report by January 24, 2022, and responsive briefs and/or expert reports (addressing the other parties' January 24 submissions) by January 26, 2022.[6] On January 27 and 28, 2022, the Special Master held a two-day evidentiary hearing, during which the parties presented expert witnesses who testified in support of the parties' respective maps.[7]

On February 7, 2022, the Special Master issued a Report containing proposed findings of fact and conclusions of law; recommending that this Court adopt HB 2146, one of the 13 plans that had been submitted for the Special

[5] *See* Veto Message, Office of the Governor of the Commonwealth of Pennsylvania (Jan. 26, 2022), https://www.governor.pa.gov/wp-content/uploads/2022/01/20220126-HB-2146-Veto-Message.pdf.

[6] All *amicus* participants were permitted to submit to the Commonwealth Court one proposed plan, and a supporting brief and/or expert report, by January 24, 2022.

[7] The *amicus* participants were not permitted to participate in the evidentiary hearing.

Master's consideration; and recommending certain modifications to the pre-primary congressional election calendar.

III. THIS COURT'S *DE NOVO* STANDARD OF REVIEW

"[I]n matters such as these where [this Court] ha[s] exercised plenary jurisdiction and ha[s] not relinquished that jurisdiction to the tribunal which is … acting as a special master for this Court, [the Court's] review must be *de novo*." *Annenberg v. Commonwealth*, 757 A.2d 338, 342–43 (Pa. 2000) (emphasis added); *LWV I*, 178 A.3d at 802 n.62 ("Given that this case is before us following our grant of extraordinary jurisdiction, our standard of review is *de novo*.").

When addressing a special master's factual findings, the Court "will afford them due consideration," but they "are not binding." *Annenberg*, 757 A.2d at 343.[8] This Court has the authority to reject the Special Master's recommendation of HB 2146 and to either (1) select one of the other congressional district plans submitted for consideration in the proceedings below or (2) assume itself the responsibility for drafting a new plan. *See, e.g.*, *League of Women Voters v. Commonwealth*, 181 A.3d 1083, 1084-88 (Pa. 2018) ("*LWV II*").

[8] As the Commonwealth Court stated in its Report, once this Court exercised extraordinary jurisdiction, the Commonwealth Court "proceed[ed] on the assumption that its credibility and weight determinations and other rulings are not entitled to any form of deference by the Supreme Court, which may substitute its judgment for that of this Court at will." Report at 16 n.26.

IV. THE *LEAGUE OF WOMEN VOTERS* FRAMEWORK

As crystallized by the evidentiary hearing conducted by the Commonwealth Court, this case presents important constitutional issues that *LWV I* expressly anticipated but did not need to resolve. This case provides an important opportunity for this Court to further develop the *LWV I* framework, to assist future legislatures' and governors' consideration of districting plans and to help guide courts traversing the "rough terrain" of judicial redistricting. *Carter v. Chapman*, 7 MM 2022, 2022 WL 304580, at *3 (Pa. Feb. 2, 2022) (Dougherty, J., concurring).

LWV I held that the Pennsylvania Constitution's Free and Equal Elections Clause "mandates that all voters have an equal opportunity to translate their votes into representation." 178 A.3d at 804; *see also id.* at 814 (explaining that the Clause "provides the people of this Commonwealth an equally effective power to select the representative of [their] choice, and bars the dilution of the people's power to do so"). Conversely, if "all voters do not have an equal opportunity to translate their votes into representation[,] [t]his is the antithesis of a healthy representative democracy." *Id.*

To help advance the Pennsylvania Constitution's guarantee of "fair and equal elections for all of our Commonwealth's voters," this Court has identified well-established "neutral criteria"—"compactness, contiguity, minimization of the division of political subdivisions, and maintenance of population equality among

congressional districts"—that "provide a 'floor' of protection for an individual against the dilution of his or her vote in the creation of such districts." *Id.* at 816-17. But these criteria are just that—a floor. *LWV I* recognized that a district plan could satisfy these criteria and "nevertheless operate to unfairly dilute the power of a particular group's vote for a congressional representative," such as by entrenching partisan advantage. *Id.* at 817.

Because *LWV I* could "be resolved solely on the basis of consideration of the degree to which neutral criteria were subordinated to the pursuit of partisan political advantage," the Court did not have to "address at th[at] juncture the possibility" of a map that satisfied the traditional floor criteria but nonetheless entrenched a structural partisan bias, thereby failing to provide all voters an equal opportunity to elect their representative of choice. *Id.* at 817. But the *LWV I* Court

> foresaw the day when this floor might require additional construction. [The Court] emphasized "the overarching objective … of our constitution is to prevent dilution of an individual's vote by mandating that the power of his or her vote in the selection of representatives be equalized to the greatest degree possible with all other Pennsylvania citizens."

Carter, 2022 WL 304580, at *5 (Dougherty, J., concurring) (quoting *LWV I*, 178 A.3d at 817).

The day has now come for the Court to build on the foundation that *LWV I* erected. In that case, the Court was considering whether to invalidate an enacted plan on the grounds that it violated the Free and Equal Elections Clause of the

Pennsylvania Constitution. Here, by contrast, there is no enacted plan; rather, the Court is reviewing many plans with the goal of adopting a map that *best* realizes "the constitutional standards in all pertinent respects." *Mellow*, 607 A.2d at 218. "[A]dopting or creating a judicial redistricting plan is a far different beast than assessing the constitutionality of an existing legislative plan; the latter is guided by a set of 'neutral criteria' that [this Court has] said 'provide a 'floor' of protection'"; this Court, however, "ha[s] yet to establish how, in the former scenario, a court is to select a particular plan in a vacuum, especially where multiple proposals may meet the constitutional floor." *Carter*, 2022 WL 304580, at *4 (Dougherty, J., concurring) (quoting *LWV I*, 178 A.3d at 817).

Although *LWV I* does not explicitly state how courts should proceed in these circumstances, the Court did provide a roadmap for the appropriate inquiry. ***First***, the Court should eliminate any proposed plan that does not comport with the *LWV I* "neutral 'floor' criteria." 178 A.3d at 817. ***Second***, because "congressional districting maps, … although minimally comporting with the[] neutral 'floor' criteria, [may] nevertheless operate to unfairly dilute the power of a particular group's vote for a congressional representative," *id.*, the Court should then select, among the remaining candidates, the plan that best "prevent[s] dilution of an individual's vote by [ensuring] that the power of his or her vote in the selection of

representatives [is] equalized to the greatest degree possible with all other Pennsylvania citizens," *id.*

LWV I provides ample instruction about how courts should, at step one of their analysis, narrow the field of proposed redistricting plans to those that satisfy the "floor" criteria. *See* 178 A.3d at 817. But that is only half of the task here. At the second step of their review, courts should select the proposed plan that is most likely to provide voters an equal opportunity to translate their votes into representation, and that is least likely to cause systematic vote dilution. *See id.* As this Court's precedents and other courts' approaches demonstrate, a key to protecting against vote dilution is to ensure that a map does not entrench a structural partisan advantage, which creates a situation in which one party, when receiving less than 50% of the votes, will systematically tend to obtain more than 50% of the representation.

In *Mellow*, the Court assessed whether a proposed map was "politically fair" before ultimately selecting a map that "result[ed] in a politically fair balance in the Pennsylvania delegation between Democrats and Republicans." 607 A.2d at 210. And in *LWV I*, even after concluding that the at-issue 2011 Plan failed to satisfy the "floor" criteria, the Court further assessed the Plan's dilutive "unfair partisan advantage" by looking to statistical measures of partisan fairness, like the Plan's "mean-median vote gap" and "efficiency gap." 178 A.3d at 820. Relying on those

additional partisan fairness metrics, the Court reaffirmed its conclusion that the "the 2011 Plan consistently work[ed] toward and accomplishe[d] the concentration of the power of historically-Republican voters and, conversely, the corresponding dilution of [voters]' power to elect their chosen representatives." *Id.*

Other courts across the country have likewise relied on the same or similar metrics, including mean-median score and efficiency gap, to ensure partisan fairness in redistricting. *See, e.g.*, *Harper v. Hall*, 413PA21, 2022 WL 343025, at *2 (N.C. Feb. 4, 2022) (advocating for use of "mean-median difference analysis, efficiency gap analysis, close-votes, close seats analysis, and partisan symmetry analysis," and stating that "[i]f some combination of these metrics demonstrates there is a significant likelihood that the districting plan will give the voters of all political parties substantially equal opportunity to translate votes into seats across the plan, then the plan is presumptively constitutional"); *see also Adams v. DeWine*, --- N.E.3d ---, 2022 WL 129092, *14 (Ohio Jan. 14, 2022) (using "efficiency gap," "mean-median gap," and "partisan symmetry" to measure fairness of proposed plan). Thus, at step two of selecting a redistricting plan, the Court should conduct a partisan fairness analysis to determine which maps are fairest and most likely to prevent vote dilution.

This approach is consonant with Pennsylvania precedent. In 2018, this Court reviewed the 2011 Plan. First, the Court determined that that the 2011 Plan

"subordinate[d] the traditional redistricting criteria in the service of partisan advantage[.]" *LWV I*, 178 A.3d at 818. And second, after applying the neutral criteria, the Court looked at additional metrics measuring the 2011 Plan's partisan fairness, concluding that a "multitude of evidence"—such as the plan's "mean-median vote gap" and "efficiency gap" scores—established that the 2011 Plan "consistently work[ed] toward and accomplishe[d] the concentration of the power of historically-Republican voters and, conversely, the corresponding dilution of Petitioners' power to elect their chosen representatives." *Id.* at 820. In other words, even if the 2011 Plan had satisfied the floor criteria at *LWV I* step one, it would have failed the partisan fairness test at *LWV II* step two.

In sum, this case requires the Court to resolve constitutional questions with profound implications for the health of Pennsylvania's democracy and the responsiveness and accountability of Pennsylvanians' elected representatives. As the Court observed in *LWV I*, "[i]t is a core principle of our republican form of government 'that the voters should choose their representatives, not the other way around.'" 178 A.3d at 740-41 (citation omitted). To ensure that Pennsylvania's new congressional map embodies that principle, the Court should eliminate any proposed redistricting plan that does not meet the *LWV I* floor, and select the remaining plan that best realizes the goals of the Free and Equal Elections Clause.

V. GOVERNOR WOLF'S PROPOSED REDISTRICTING PLAN

A. Creation of the Governor's Plan

As the only party to this litigation who has a constituency of, and thus represents the interests of, all Pennsylvania voters, the Governor has played an active role in advocating for a fair and transparent redistricting process. In September 2021, the Governor issued an Executive Order creating the Pennsylvania Redistricting Advisory Council, a six-member council comprised of experts in various disciplines relevant to redistricting, from law to political science to mathematics, which was formed to provide guidance to the Governor and assist his review of any congressional redistricting plan passed by the General Assembly.[9]

At the same time, Governor Wolf announced the opening of a redistricting public comment portal website, for members of the public to submit proposed maps, outline communities of interest, and provide comments to help shape the outcome of this critical part of our democratic process.[10] The Redistricting Council

[9] Commonwealth of Pennsylvania Governor's Office, Executive Order 2021-05 (Sept. 13, 2021), https://www.governor.pa.gov/wp-content/uploads/2021/09/20210913-EO-2021-05-Redistricting-Advisory-Council.pdf; *see also* Press Release, Office of Governor Tom Wolf, *Governor Wolf Creates Redistricting Advisory Council to Help Evaluate Fairness in Upcoming Congressional Redistricting Map* (Sept. 13, 2021), https://www.governor.pa.gov/newsroom/governor-wolf-creates-redistricting-advisory-council-to-help-evaluate-fairness-in-upcoming-congressional-redistricting-map/.

[10] Press Release, Office of Governor Tom Wolf, *Governor Wolf Creates Redistricting Advisory Council to Help Evaluate Fairness in Upcoming Congressional Redistricting Map*

held nine hearings throughout the state to accept testimony from the public on a set of Redistricting Principles to help guide the Governor's review of any congressional district plan passed by the General Assembly. Derived from Pennsylvania and U.S. Supreme Court precedent, these Redistricting Principles were finalized by the Council and made public by the Governor on November 24, 2021[11]:

- **Legal Principles**
    - Each district should be as nearly equal in population as practicable;
    - All territory within a district should connect to the rest of the district, and the plan should disfavor a district with territory only connected at a narrow single point;
    - The plan should provide geographic compactness unless dispersion is required to advance another positive districting principle;
    - The plan should prioritize fewer subdivision splits unless necessary to preserve a cohesive–and clearly identified–community of interest;
    - The General Assembly should consider whether the Voting Rights Act requires the creation of proposed majority-minority districts.
- **Principles of Representation**
    - The plan should maintain communities of interest,
    - Composition of the congressional delegation under the plan should be proportional to statewide voter preference;

(Sept. 13, 2021), https://www.governor.pa.gov/newsroom/governor-wolf-creates-redistricting-advisory-council-to-help-evaluate-fairness-in-upcoming-congressional-redistricting-map/.

[11] *See* Press Release, *Gov. Wolf Announces Pennsylvania Redistricting Advisory Council's Redistricting Principles* (Nov. 24, 2021), https://www.governor.pa.gov/newsroom/gov-wolf-announces-pennsylvania-redistricting-advisory-councils-redistricting-principles/.

- The plan should yield election results responsive to changing voter preference.

- **Principles of Process**

  - The General Assembly's proposal should include an explanation of specific decisions, such as the communities of interest and how they were defined and the factors that led to the creation of a majority-minority districts.

Further, during the General Assembly's deliberations, the Governor provided public feedback on proposed maps,[12] and publicly disclosed and highlighted the Governor's Plan as an example of new congressional district boundaries that are consistent with the Redistricting Principles, free of gerrymandering, and in full accord with United States and Pennsylvania Supreme Court precedent.[13]

B. The Governor's Plan Exemplifies the Principles Discussed in *LWV I*

Now that the Governor's Plan has been subjected to close expert scrutiny, the evidence shows that the Governor's Plan is a standout choice among the 13 plans submitted for consideration. As demonstrated through the proceedings before the Special Master, Pennsylvanians can—and should—have a congressional districting plan that (1) satisfies the neutral "floor" criteria; and (2) exemplifies

[12] *See* note 4, *supra*.

[13] *See* Governor Tom Wolf, *Congressional Districts Map Proposals* (Jan. 15, 2022), https://www.governor.pa.gov/congressional-districts-map-proposals/.

partisan fairness, providing all Pennsylvanians an equal opportunity to "select the congressional representative of his or her choice." *LWV I*, 178 A.3d at 816. *See, e.g.*, Report at 73 (FF104); Tr. 319:1-8, 382:7-11, 385:1-20. The Governor's plan does both, as the evidence—including the testimony of the Governor's expert, Dr. Moon Duchin, a renowned mathematician and leading redistricting expert—clearly showed: The Governor's Plan (1) does an excellent job of satisfying the traditional criteria (both the neutral "floor" criteria and the other traditional criteria noted in *LWV I*), while also (2) achieving partisan fairness. *See, e.g.*, Report at 79-83 (FF138, FF148, FF158-59); Tr. 338:19-24, 349:15-350:7, 385:1-20. Indeed, it is the only plan submitted by any party to be in the top tier for both sets of metrics.

1. The Governor's Plan Satisfies the "Floor" Criteria

Considered at "step one" of the *LWV I* framework (*see* § IV, *supra*), the Governor's Plan is one of the best plans on the traditional criteria of compactness, contiguity, population equality, and maintaining political subdivisions. *See* **Ex. 1**, Duchin Report at 5-9; **Ex. 2**, Duchin Response Report at 2-3; Tr. 334:15-335:10, 337:12-338:5, 493:5-15. Specifically, based on her quantitative analysis, Dr. Duchin concluded that the Governor's Plan merited placement in the top tier of proposed plans, based on its adherence to the traditional criteria. **Ex. 2**, Duchin Response Report at 3. Although all proposed plans maintain population equality and are contiguous, Dr. Duchin concluded that the Governor's Plan achieved

exemplary compactness while still maintaining political subdivisions, making it one of the very best plans when assessed under the traditional criteria:

Compactness

	block cut edges (lower is better)	average Polsby-Popper (higher is better)	average Reock (higher is better)
GovPlan	5185	0.381	0.431
CitizensPlan	5266	0.376	0.451
HB-2146	5907	0.321	0.409

	average Schwartzberg (higher is better)	average convex hull (higher is better)	average pop. polygon (higher is better)
GovPlan	1.653	0.826	0.783
CitizensPlan	1.669	0.812	0.772
HB-2146	1.820	0.799	0.752

Ex. 1, Duchin Report at 9, Table 3.

Table 1: Comparison of compactness and splitting metrics.

name	mean Polsby	mean Schwartz	mean Reock	mean ConvHull	mean PopPoly	cut edges	split counties	county pieces	split munis	muni pieces
GovPlan	0.3808	1.6534	0.4313	0.8257	0.7834	5185	16	35	18	37
CitizensPlan	0.3785	1.6625	0.4512	0.8120	0.7725	5237	14	30	16	33
HB-2146	0.3212	1.8197	0.4087	0.7987	0.7524	5907	15	33	16	34
Carter	0.3214	1.8103	0.4499	0.7922	0.7416	5926	14	31	20	41
Gressman/GMS	0.3478	1.7351	0.4261	0.8176	0.7582	5582	15	32	16	33
HouseDemCaucus	0.2787	1.9693	0.4286	0.7717	0.7205	6853	16	34	18	37
SenateDemCaucus1	0.3147	1.8144	0.4137	0.7918	0.7519	6047	17	36	19	39
SenateDemCaucus2	0.3346	1.7478	0.4146	0.8153	0.7601	5505	16	34	16	33
Reschenthaler1	0.3629	1.6859	0.4347	0.8238	0.7737	5090	13	29	16	33
Reschenthaler2	0.3524	1.7127	0.4231	0.8161	0.7658	5237	13	29	16	33
CitizenVoters	0.3490	1.7133	0.4412	0.8082	0.7575	5173	14	31	16	33
VotersOfPA	0.3965	1.6069	0.4697	0.8209	0.7681	5052	15	31	18	37
KhalifAli	0.3523	1.7204	0.4448	0.8111	0.7456	5266	16	35	18	37

Ex. 2, Duchin Response Report at 2, Table 1.

As all the experts who testified at the hearing agreed, there are inherent trade-offs among the various floor criteria in redistricting; there is no "perfect map."[14] *See also* Section VI(C)(3), *infra*. But the evidence showed that the

[14] *See* Tr. 94:25-95:13, 106:1-6 (Rodden); *id.* at 211:11-212:9, 215:17-216:9 (DeFord); *id.* at 338:6-18, 339:12-342:11 (Duchin); *id.* at 627:13-628:13 (Barber); *id.* at 764:25-765:13, 829:19-830:3 (Naughton).

Governor's Plan does an excellent job of balancing those trade-offs.[15] This evidence was by no means limited to Dr. Duchin's testimony. The analysis of other experts underscored that the Governor's Plan amply satisfied—indeed, excelled under—the traditional redistricting criteria.[16] (By contrast, HB 2146 should be eliminated from consideration at this stage, as it is the same as or worse than other maps, such as the Citizens/Draw the Lines Plan, on every metric in the above Table 1.)

2. The Governor's Plan Achieves Partisan Fairness

As described above, the Court must be mindful that "congressional districting maps, … although minimally comporting with the[] neutral 'floor' criteria, [may] nevertheless operate to unfairly dilute the power of a particular group's vote for a congressional representative." *LWV I*, 178 A.3d at 817. As a result, at "step two" of the *LWV I* framework for selecting a redistricting plan (*see* § IV, *supra*), the Court should conclude that, of the remaining proposed plans, the Governor's Plan best achieves partisan fairness and promotes accountability and

[15] The Governor's Plan also performs on a high level with respect to the other "traditional" criteria identified in *LWV I* as secondary to the "floor" criteria—*i.e.*, the principles of "least change," protection of incumbents, and communities of interest. *See* **Ex. 1**, Duchin Report at 6-12; Tr. 342:12-343:11, 347:7-23-349:7.

[16] *See, e.g.*, Barber Rebuttal Report at 8, Table 1 (Governor's Plan had second best Polsby-Popper compactness score of all plans); DeFord Rebuttal Report at 9 (Governor's Plan had two best, one second best, and one fourth best score on compactness); Rodden Response Report at 2 (districts in Governor's Plan retain the fourth highest population share compared to the 2018 Remedial Plan).

responsiveness to voters, thereby making good on the promise of the Free and Equal Elections Clause to "provide[] the people of this Commonwealth an equally effective power to select the representative of his or her choice, and bar[] the dilution of the people's power to do so." *Id.* at 814.

Evaluated at "step two" of the *LMV I* framework, the Governor's Plan ranks among the top plans based on various statistical measures of partisan fairness, including the "mean-median" and "efficiency gap" scores relied on by this Court in *LWV I* and by other courts across the country. As Dr. Duchin explained, the closer each of these four scores are to zero, the better (and more fair) the plan; negative scores reflect Republican advantage, and positive scores reflect Democratic advantage. Tr. 371:18-24; *see also* **Ex. 1**, Duchin Report at 17.

Table 3: Comparison of all plans under four metrics of fairness in the economics and political science literature.

	total efficiency gap	total Eguia metric	total mean-median	total partisan bias
GovPlan	0.1007	−0.0486	−0.0077	−0.1176
CitizensPlan	−0.1678	−0.3427	−0.1042	−0.6471
HB-2146	−0.8336	−0.9898	−0.2927	−1.2353
Carter	−0.0058	−0.1663	−0.113	−0.5294
Gressman/GMS	0.1394	−0.0486	−0.0385	−0.2353
HouseDemCaucus	0.1814	0.0102	−0.0071	0.1765
SenateDemCaucus1	−0.2601	−0.4015	−0.1382	−0.7059
SenateDemCaucus2	0.1221	−0.0486	0.0106	0.1176
Reschenthaler1	−1.1024	−1.2251	−0.2524	−1.1176
Reschenthaler2 2	−1.1042	−1.2251	−0.2534	−1.0588
CitizenVoters	−0.4074	−0.5192	−0.1847	−0.6471
VotersOfPA	−0.5686	−0.6957	−0.2734	−0.8824
KhalifAli	−0.3166	−0.4604	−0.1209	−0.4706
ensemble mean	−0.6755	−0.8451	−0.2872	−1.1437

Ex. 2, Duchin Response Report at 4, Table 3;[17] *see also* **Ex. 1**, Duchin Report at 13-19; Tr. 369:3-375:11.

Dr. Duchin explained that, when it came to metrics measuring fairness, the Governor's Plan was "excellent across the board," and that "in all four of the [fairness] metrics" Dr. Duchin reported in Table 3 above, the Plan "gives scores that are either the closest or nearly the closest to zero." Tr. 372:3-8. In other words, the Governor's Plan is on the "*Pareto frontier*" of the dataset on the fairness metrics, given that, in assessing how the 13 plans optimize multiple objectives, the Governor's Plan "dominates" (is equal to or better than in every metric) ten plans and is in a trade-off position with the other two. *See* **Ex. 2**, Duchin Response Report at 4; Tr. 372:19-374:5. Other experts recognized the excellence of Dr. Duchin's analysis,[18] and to the extent the other parties' experts conducted credible statistical analyses comparing the plans, their analyses confirm the exemplary

[17] Dr. Duchin quantified each map's (1) "efficiency gap," which is "based on the idea of wasted votes, defined as any winning votes in excess of 50%, or any losing votes at all"; (2) "Eguia's artificial partisan advantage," which "compares the outcomes under districted plurality elections to the outcomes under ostensibly neutral political subdivisions, such as counties"; (3) "mean-median score," which indicates "how much of the vote in a state is needed to capture half of the representation"; and (4) "partisan bias score," or "how much of the representation would be captured by each party if the election underwent a uniform partisan swing to a 50-50 share." **Ex. 1**, Duchin Report at 17.

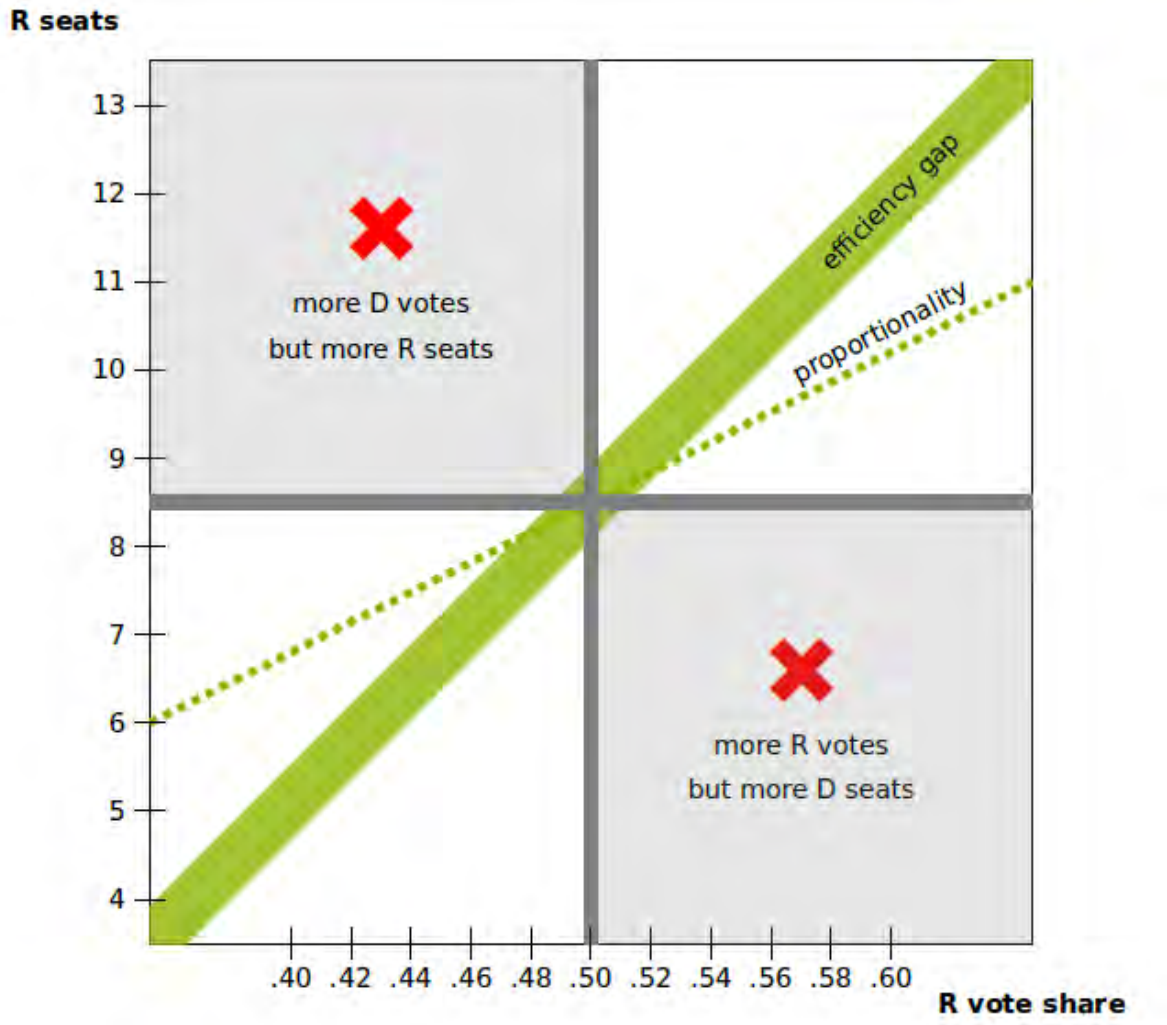
[18] *See* Tr. 981:12-17 (Professor Devin Caughey testified: "the reports that I've seen and the testimony that I saw from other experts, especially from . . . Moon Duchin, was excellent, and I have no reason to doubt anything that she said").

fairness of the Governor's Plan.[19] Moreover, as shown in Table 3 above, not only is the Governor's Plan one of the (if not the) fairest proposals, but the proposal recommended by the Special Master, HB 2146, is the least fair proposal, scoring worse than even the "ensemble" mean (meaning HB 2146 is less fair than the average of 100,000 randomly-drawn districting plans that already show inherent Republican bias). **Ex. 2**, Duchin Response Report at 4, Table 3.

In addition to the partisan fairness metrics discussed above, Dr. Duchin also employed an "overlay" method, in which she overlaid several plans, including the Governor's Plan and HB 2146, on a sequence of statewide elections in Pennsylvania to assess whether close vote margins resulted in a close split in the number of seats won (the "Close-Votes-Close-Seats Principle"). **Ex. 1**, Duchin Report at 13.[20] As depicted in the figure below, if an election is near even (placing it horizontally near the center of the plot), then the corresponding data point should, from a fairness perspective, tend to fall at the bulls-eye in the middle of the plot rather than falling consistently above or below the target.

[19] *See, e.g.*, Tr. 266:14-21 (Dr. DeFord testifying that the Governor's Plan and the Carter Plan are the "best performing maps" using the mean efficiency gap score for partisan fairness); *id*. at 972:8-18 (Professor Caughey testifying that the Governor's Plan rated "very similarly on partisan fairness metrics" to the 2018 Remedial Plan adopted by the Pennsylvania Supreme Court); Caughey Response Report at 2 (concluding that the Governor's Plan is "by far" more fair than HB 2146).

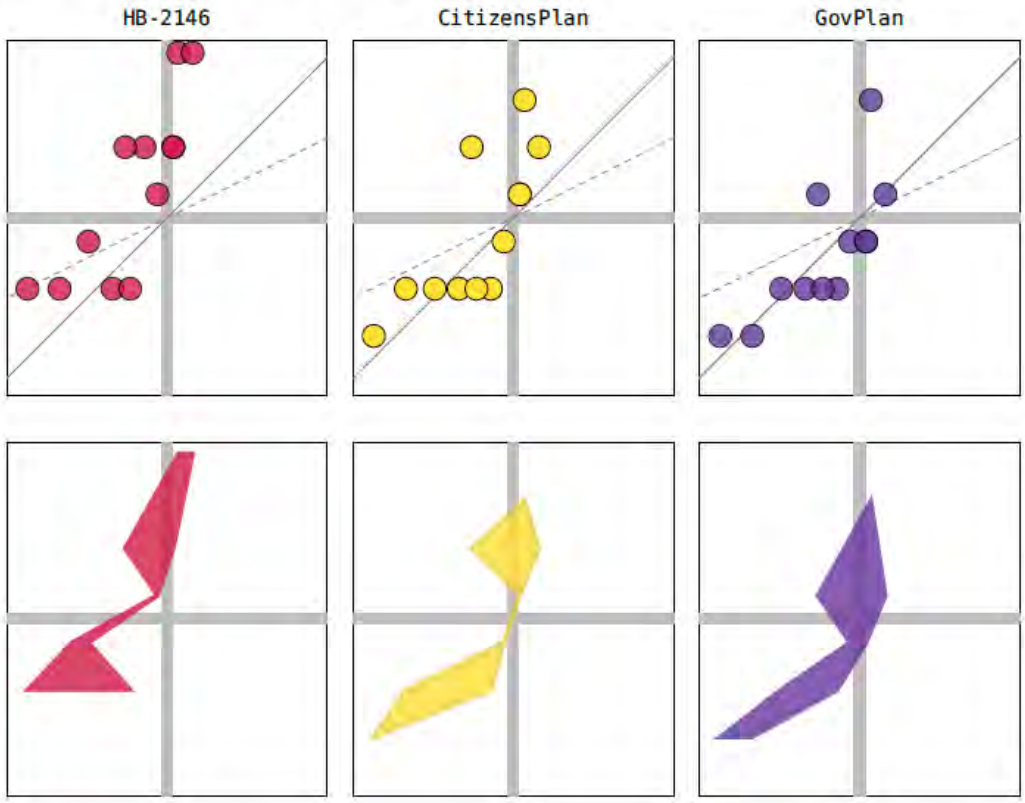
[20] As noted above, the North Carolina Supreme Court recently voiced its support for Dr. Duchin's "Close-Votes-Close-Seats Principle." *Harper*, 2022 WL 343025, at *2.



Ex. 1, Duchin Report at 14, Figure 4.

Applying these principles to the plans, Dr. Duchin demonstrated that HB 2146 nearly always misses the bulls-eye, while the Governor's Plan generally hits and tightly circles the bulls-eye. *Id.* at 16. Dr. Duchin summarized HB 2146's performance as "consistently converting close elections to heavy Republican representational advantages"; by contrast, the Governor's Plan "does an excellent job of hitting that [bulls-eye] target." Tr. 364:20-365:9.

Figure 6: This time, the three new proposed plans are overlaid on the same elections. HB-2146 entrenches a Republican advantage, while CitizensPlan and especially GovPlan are far superior at leveling the partisan playing field.



Ex. 1, Duchin Report at 16, Figure 6. (The "CitizensPlan" graph depicts the results of elections under a version of a plan submitted by Draw the Lines PA.)

3. The Governor's Plan Is in the Top Tier on *Both* the Neutral Floor Criteria and Partisan Fairness

As Dr. Duchin concluded, only the Governor's Plan is in the top tier of the proposed plans at *LWV I* step one, *i.e.*, satisfies the floor criteria even if the floor is set very high, *and* is in the top tier of plans at *LWV I* step two, by demonstrating excellent partisan fairness. *See* **Ex. 2**, Duchin Response Report at 5. If the concept of tiers is employed—with the top tier of plans being on the "Pareto frontier," *i.e.*, plans that manage the tradeoffs as well as or better than any other option—then it

is reasonable to ask which plans are in the top tier for both the traditional principles and for partisan fairness metrics. As Dr. Duchin testified, "it turns out there's only one map in both sets, and that's the Governor's plan." Tr. 393:18-25. Put differently, the Governor's Plan meets and then rises above the floor set by *LWV I*: it provides Pennsylvanians with an equal opportunity to translate their political preferences into representation, thus ensuring that the Commonwealth's elected representatives will be responsive and accountable to the Commonwealth's voters.

In sum, the evidence shows that the Governor's Plan best realizes the goals set forth by this Court in *LWV I*, guaranteeing "that the power of [a Pennsylvanian's] vote in the selection of representatives [is] equalized to the greatest degree possible with all other Pennsylvania citizens," *LWV I*, 178 A.3d at 817. Particularly in light of the deep flaws in the Special's Master's recommendation of HB 2146 discussed below, Governor Wolf respectfully requests that the Court adopt the Governor's Plan.

VI. EXCEPTIONS TO THE SPECIAL MASTERS' PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW

A. Overview of Exceptions

When assessed using the neutral criteria and principles of fairness set forth in *LWV I*, HB 2146 is a demonstrably poor performer. Among the 13 plans submitted in these proceedings, HB 2146 consistently ranks at or near the bottom

of the pack under all metrics. In selecting HB 2146 in spite of its measureable, pervasive weaknesses, the Special Master made two categorical errors.

First, the Special Master incorrectly determined which elements of expert testimony to credit and which to discount. That error was endemic, tainting all of the Special Master's conclusions and, in particular, the Report's assessment of the proposed plans' performance using partisan fairness metrics.

Second, as reflected in the chart below, the Special Master systematically discarded the better and fairer plans—one by one—in reliance on a misunderstanding of what *LWV I* and the Free and Equal Elections Clause endeavor to protect (namely, fundamental fairness and equal participation in the electoral process).

Summary of Special Master's Analysis

No.	Proposed Plan	Special Master's Reasons for Criticizing / Disqualifying Plan
1	**Carter Plan** (Plan offered by Carter Petitioners, developed by Dr. Jonathan Rodden)	• Population Equality: Results in districts with a two-person deviation (Report at 192 ¶ 18, 204) • Incumbent Pairings: Includes two Republicans in one district (*id.* at 195 ¶ 32, 204-05)[21] • Least Change: Employs a "least change" approach based on a prior court-made plan (*id.* at 195 ¶¶ 34-36, 204) • Unfair Partisan Gerrymandering: Purportedly yields a partisan advantage to Democratic Party based on efficiency gap score (*id.* at 197 ¶¶ 40-43, 205)
2	**Gressman Plan** (Plan offered by Gressman Petitioners, developed through mathematical optimization techniques)	• Communities of Interest: Fails to consider communities of interest (*id.* at 156 (FF10), 205) • Proportionality/Partisan Fairness: Was purposefully created with algorithm designed to optimize partisan fairness (*id.* at 178 (FF2), 205) • Unfair Partisan Gerrymandering: Purportedly yields a partisan advantage to Democratic Party based on efficiency gap and mean-median scores (*id.* at 197 ¶¶ 40-43, 205)

[21] On the topic of incumbent pairings, the final "Recommendations" section of the Special Master's Report criticized ***only*** the Senate Democratic Caucus Plan 1 and the Carter Plan for "including two Republican incumbents in one congressional district." *See* Report § VI at 195 ¶ 32. By contrast, in its Findings of Fact Section (Section V), the Report concluded that, while the Senate Democratic Caucus Plan 1 and the Carter Plans each have only *one* significant incumbent pairing, five *other* plans (the Reschenthaler 1, Citizens Voters, Draw the Lines, Senate Democratic Caucus 2, and House Democratic Caucus plans) fare worse by having *two* significant incumbent pairings. For those five plans, the Commonwealth Court concluded in its Findings of Fact that because they pair *three* incumbents of one party, but only *one* incumbent of the other party, they "will be given less weight in this regard." *Id.* at 180-83 (FF16-28). The Report does not mention in its final Recommendations section, however, the fact that these other five plans include *two* significant incumbent pairings.

No.	Proposed Plan	Special Master's Reasons for Criticizing / Disqualifying Plan
3	**Governor's Plan** (Plan offered by the Governor, developed by the Governor's office and taking account of submissions to a public portal)	• Political Subdivision Splits: Divides Pittsburgh and Bucks County into two congressional districts (*id.* at 194-95 ¶¶ 25-31, 200) • Compactness: Plan's excellent compactness score should be discounted due to split of Pittsburgh (*id.* at 148 (FF4; CL)) • Unfair Partisan Gerrymandering: Purportedly yields a partisan advantage to Democratic Party based on efficiency gap score (*id.* at 197 ¶¶ 40-43, 201)
4	**Senate Democratic Caucus Plan 1** (First plan offered by the Senate Democratic Caucus)	• Political Subdivision Splits: Divides Pittsburgh into two congressional districts (*id.* at 194-95 ¶¶ 25-30, 202) • Incumbent Pairings: Includes two Republicans in one district (*id.* at 195 ¶ 32, 202)[22]
5	**Senate Democratic Caucus Plan 2** (Second plan offered by the Senate Democratic Caucus)	• Political Subdivision Splits: Divides Pittsburgh into two congressional districts (*id.* at 194-95 ¶¶ 25-30, 202) • Unfair Partisan Gerrymandering: Purportedly yields a partisan advantage to Democratic Party based on efficiency gap score (*id.* at 197 ¶¶ 40-43, 202)[23]
6	**House Democratic Caucus Plan** (Plan offered by the House Democratic Caucus)	• Population Equality: Results in districts with a two-person deviation (*id.* at 192 ¶ 18, 203) • "Oddly Shaped" District: Draws an oddly shaped "Freddy-Krueger like claw" district in Allegheny County (*id.* at 203) • Unfair Partisan Gerrymandering: Purportedly yields a partisan advantage to Democratic Party based on efficiency gap and mean-median scores (*id.* at 197 ¶¶ 40-43, 203)[24]

[22] *But see* note 21, *supra*. Additionally, notwithstanding that the Report did not find that Senate Democratic Caucus Plan 1 provides a Democratic advantage based on its efficiency score (and it does not), the Report incorrectly stated that it does so in its Recommendations section, grouping Senate Democratic Caucus Plan 1 with Senate Democratic Caucus Plan 2. Report at 201-02 no. 5.

[23] *See also* note 21, *supra*.

[24] *See also* note 21, *supra*.

No.	Proposed Plan	Special Master's Reasons for Criticizing / Disqualifying Plan
7	**Draw the Lines Plan** (Plan offered by amicus participants Draw the Lines PA project affiliates, derived from citizen-submitted contest entries in Draw the Lines PA competition)	• Political Subdivision Splits: Divides Pittsburgh into two congressional districts (*id.* at 194-95 ¶¶ 25-30, 201) • Proportionality/Partisan Fairness: Splits Pittsburgh to "maximize political competitiveness" (*id.* at 178 (FF3), 201) • Unfair Partisan Gerrymandering: Purportedly yields a partisan advantage to Democratic Party based on efficiency gap score (*id.* at 197 ¶¶ 40-43, 201)[25]
8	**Ali Plan** (Plan offered by amicus participants Khalif Ali et al., on behalf of the Public Interest Law Center)	• Population Equality: Relies on prisoner-adjusted population data set (*id.* at 192-93 ¶¶ 19-21, 199) • Political Subdivision Splits: Divides Pittsburgh into two congressional districts (*id.* at 194-95 ¶¶ 25-30, 199-200)
9	**HB 2146** (Plan offered by the Republican Legislative Intervenor-Respondents; derived from plan by citizen Amanda Holt; was modified and then passed by the House of Representatives, then passed by the Senate)	*No issues identified*
10	**Reschenthaler Plan 1** (First plan offered by Congressman Reschenthaler et al.)	*No issues identified*[26]
11	**Reschenthaler Plan 2** (Second plan offered by Congressman Reschenthaler et al.)	*No issues identified*

[25] *See also* note 21, *supra*.

[26] *See also* note 21, *supra*.

No.	Proposed Plan	Special Master's Reasons for Criticizing / Disqualifying Plan	
12	**Voters of PA Plan** (Plan offered by "Voters of the Commonwealth of Pennsylvania" amicus participants, Pennsylvania residents who intend to support Republican candidates in the 2022 elections)		*No issues identified*
13	**Citizens Voters Plan** (Plan offered by "Citizens Voters" amicus participants)	• Communities of Interest: Fails to show that the plan preserved communities of interest (*id.* at 156 (FF11), 204) • Population Equality: Results in districts with a two-person deviation (*id.* at 204)[27]	

1. The Special Master Selectively Applied the Neutral Criteria and Partisan Fairness Metrics to Disqualify the Statistically Best-Performing, Most Fair Plans

In disqualifying plans seriatim, the Special Master misapplied specific redistricting criteria (often taking an inconsistent approach with each plan) to critique or eliminate various proposals. Perhaps most notably, although the Special Master initially purported to give "less weight" to plans that split Pittsburgh, *see* Report at 151-52 (FF19), in practice the Special Master appears to have treated splitting Pittsburgh (and Bucks County) as *per se* disqualifying. Report at 195 ¶¶ 30-31. That was error: (1) almost all experts recognized that line-drawing in redistricting plans necessarily involves trade-offs among the various neutral

[27] The Citizens Voters Plan was not, however, one of the plans identified as having a two-person deviation in the Findings of Fact section of the Report. Report at 192 ¶ 18. *See also* note 21, *supra*.

criteria; and (2) not one of the other parties or amici sought to justify *every* political subdivision split in their proposed map—indeed, there is no legal requirement to do so. (To take just one example, the Republican Legislative Intervenor-Respondents provided no justification for HB 2146's split of Washington County, which the Governor's Plan keeps together.) Further, the Report inconsistently applied partisan fairness metrics to eliminate plans broadly acknowledged to have high marks on partisan fairness, including the Governor's Plan.

2. The Special Master Recommended Adoption of HB 2146 Despite Its Being One of the Least Compact Plans, with the Worst Marks on Partisan Fairness

Following the Special Master's process of elimination reflected in the above chart, four plans remained: HB 2146, both Reschenthaler plans, and the Voters of PA Plan. *See* Report at 207-08 ¶¶ 57-59. The Special Master concluded that these plans "are consistent with the Free and Equal Elections Clause of the Pennsylvania Constitution, the aspirations and ideals expressed by that constitutional provision as pronounced by the Court in *LWV II* due to their ***compactness***, ***degree of partisan fairness***, and specific development of congressional districts." *Id.* at 207 ¶ 57 (emphasis added).

In fact, and as further detailed below, HB 2146 is plainly inferior on both compactness and partisan fairness:

- ***HB 2146 consistently scores in the bottom four plans for compactness***. Its mean Polsby Popper score is 11th out of 13, its mean Schwartz score is 12th out of 13, its mean Reock score is last out of 13, its mean Convex Hull score is 10th out of 13, its mean Population Polygon score is 9th of 13, and its cut edges score is 10th of 13. **Ex. 2**, Duchin Response Report at 2.[28]

- ***HB 2146 consistently converts close votes to a marked Republican seat advantage, and HB 2146 consistently scores as the most biased plan or one of the three most biased plans*** on the four metrics Dr. Duchin employed to measure the partisan fairness of the proposed plans. Specifically, its total efficiency gap score is 11th out of 13, its total Eguia metric score is 11th out of 13, its total mean-median score is last out of 13, and its total partisan bias score is last out of 13. **Ex. 2**, Duchin Response Report at 4; *see also* **Ex. 1**, Duchin Report at 17 (describing various partisan fairness metrics).[29]

In support of its recommendation, the Report stated that the plans "proposed by Voters of PA *Amici*, Reschenthaler 1, and HB 2146 comply with the various experts' universal recognition that the surface areas comprising the district should be in accord with the natural, political, and structural geography of those areas." Report at 207 ¶ 58. But this conclusion not only misstates the testimony provided at the hearing; it is also untethered to the legal framework set out by *LWV I.* The Report then proceeded to give impermissible deference to HB 2146 based on its

[28] The Special Master found Dr. Duchin's opinion on the compactness of the 13 plans "to be credible." Report at 147 (FF1-3).

[29] Other experts likewise found that HB 2146 performs at the bottom of the pack according to partisan fairness metrics. *See* DeFord Response Report at 15 (reporting HB 2146's mean-median score as last out of the nine plans submitted by parties, and its average efficiency gap score as 7th out of those nine plans); Caughey Response Report at 22, Table 6 (reporting HB 2146's mean-median and efficiency gap scores as the worst between it, the Governor's Plan, and the Senate Democratic Caucus Plans 1 and 2). *See also* § VI(E)(3), *infra*.

passage by both chambers of the General Assembly, in spite of its ultimate veto by the Governor. *Id.* at 213-17. At the conclusion of this chain of reasoning, the Report formally recommended HB 2146 for adoption. *Id*. at 216-17 ¶ 97.

As detailed below, the fundamental flaws in the Report's analysis fatally compromise its ultimate recommendation.

B. Exception One – The Special Master's Report Committed Numerous Errors in Its Treatment of Expert Analysis and Testimony

As with its analysis of the proposed redistricting plans, the Report's assessment of the parties' expert witnesses included significant missteps. Because the Special Master discredited experts whose testimony was plainly reliable and relied on experts who were unqualified and whose methodology was flawed, the Special Master's conclusions are fundamentally compromised.

The Special Master's findings of fact regarding expert testimony are entitled to due consideration but are not binding on this Court. *See Annenberg*, 757 A.2d at 343. For an expert to be qualified, he or she must demonstrate "knowledge, skill, experience, training, or education." *See* Pa. R. Evid. 702. And although special training or experience is a necessary condition for qualification as an expert witness, it is not sufficient; the expert's testimony must be also "known to him *because of* his special training and experience." *Steele v. Shepperd*, 192 A.2d 397, 398 (Pa. 1963) (emphasis added). Further, the expert may only provide testimony

that: "is beyond that possessed by the average layperson"; "will help the trier of fact to understand the evidence or to determine a fact in issue"; and uses a "methodology . . . generally accepted in the relevant field." Pa. R. Evid. 702; *see also Grady v. Frito-Lay, Inc.*, 839 A.2d 1038, 1043–44 (Pa. 2003) ("[N]ovel scientific evidence is admissible if the methodology that underlies the evidence has general acceptance in the relevant scientific community." (citing *Commonwealth v. Blasioli*, 713 A.2d 1117, 1119 (Pa. 1998)). "[T]he proponent of expert scientific evidence bears the burden of establishing all of the elements for its admission under Pa.R.E. 702." *Grady*, 839 A.2d at 1045.

Here, there are significant errors in the Report's proposed findings about the experts. First, the Report incorrectly rejected two individual conclusions by Dr. Moon Duchin (the Governor's expert) based on the Special Master's error of arithmetic in interpreting Dr. Duchin's calculations—and despite heavily relying on Dr. Duchin's other conclusions in nearly every other facet of the Report. Second and third, the Report ignored disqualifying flaws in the qualifications and methodologies of two experts: Dr. Michael Barber and Dr. Keith Naughton. And fourth, the Report determined the declaration of Pittsburgh City Controller Michael Lamb was "unpersuasive" because of its purported reliance on "personal" experience, ignoring that Controller Lamb's declaration was offered based on his *professional* experience as Controller of the City of Pittsburgh. As discussed

below, the Court should give no credit or weight to the testimony of Dr. Barber and Dr. Naughton and should give full credit and weight to the testimony of Dr. Duchin and Controller Lamb.

1. The Report Erred in Discrediting Two Scores Reported by Dr. Duchin Based on an Error of Arithmetic in Comparing the Scores

As a general matter, the Special Master relied heavily on Dr. Duchin's testimony. From the Report's very first conclusion of law, Report at 137 (CL1), the Report credited Dr. Duchin's analysis at least 36 times.[30] The Special Master accepted or adopted Dr. Duchin's analysis on the following topics:

- Contiguity, Report at 137 (CL1);
- Political Subdivision Splits, *id.* at 142-43 (FF3-4);
- Compactness, *id.* at 147-48 (FF1-3);
- Communities of Interest, *id.* at 155 (FF6-7);
- Partisan Geography, *id.* at 164 (FF9-10); and
- Protection of Incumbents, *id.* 178-79 (FF1-3).

While generally recognizing Dr. Duchin's careful and credible analysis, the Special Master misunderstood two of Dr. Duchin's calculations of partisan fairness scores. Reviewing Dr. Duchin's "mean-median numbers" against other experts'

[30] *See* Report at 137 (CL1); 141 (FF1-4); 142-43 (FF3-4); 143 (FF12); 144 (FF16); 145 (FF28); 146 (FF31); 147 (FF42); 147-48 (FF1-4); 149 (FF7); 155 (FF6-7); 164 (FF9-10); 178-79 (FF1-3); 182 (FF3); 193 ¶ 22; 196-97 ¶ 38; and 206-07 ¶¶ 50-54.

conclusions, the Special Master concluded that Dr. Duchin's totals were "extreme outliers" and thus "not credible." *Id.* at 172 (FF26). The Special Master similarly rejected Dr. Duchin's "efficiency gap numbers" as "extreme outliers." *Id.* at 175 (FF17). But the undisputed evidence demonstrates that the Special Master misinterpreted Dr. Duchin's calculations.

Other than Dr. Duchin, the experts who conducted mean-median and efficiency gap analyses reported values as an average over the elections that they considered. It appears that the Special Master did not appreciate that Dr. Duchin's mean-median and efficiency gap calculations, as clearly identified in her response report, were presented as sum totals across all elections Dr. Duchin analyzed, rather than per-election average calculations. *See* **Ex. 2**, Duchin Response Report at 4, Table 3 (identifying "*total* mean-median" and "*total* efficiency gap") (emphasis added). In other words, for each proposed plan that she analyzed, Dr. Duchin *summed* her mean-median calculations based on results from 12 elections, and *summed* her efficiency-gap calculations based on results from 12 elections. As Dr. Duchin explained in her testimony:

> A. [I]f you wanted to turn these into something comparable to an individual election, you'd need to divide by 12 because this is the sum over 12 elections.
>
> Q. So if you divide by 12, you get a percent?
>
> A. Yes. Then you can interpret it that way.

Tr. 456:4-12.

Understanding the above, doing the simple arithmetic of dividing by 12 makes clear that Dr. Duchin's calculations were not outliers when compared to other experts' scoring. The following chart shows the Special Master's summary of various experts' mean-median differences, calculated for HB 2146:

Summary of Mean-Median Differences: HB 2146
(Report at 169 (FF14))

Expert	**Mean-Median Difference** (0 is most fair)
Dr. Barber (per election average)	-.015 (1.5% Republican advantage)
Dr. DeFord (per election average)	-.029 (2.9% Republican advantage)
Dr. Rodden (per election average)	-.024 (2.4% Republican advantage)
Dr. Duchin (sum total)	-.2927

After dividing Dr. Duchin's calculation by 12 to convert her total mean-median calculation into a per-election average, Dr. Duchin's mean median score is well within the other experts' range of scores:

Expert	**Mean-Median Difference** (0 is most fair)
Dr. Barber (per election average)	-.015 (1.5% Republican advantage)
Dr. DeFord (per election average)	-.029 (2.9% Republican advantage)
Dr. Rodden (per election average)	-.024 (2.4% Republican advantage)
Dr. Duchin (per election average)	-.024 (2.4% Republican advantage)

Repeating the same process using the Special Master's summary of various experts' efficiency-gap scores for HB 2146 yields the same results:

Summary of Efficiency Gap: HB 2146
(Report at 173 (FF7))

Expert	**Efficiency Gap** (0 is most fair)
Dr. Barber (per election average)	-.025 (2.5% Republican advantage)
Dr. DeFord (per election average)	-.063 (6.3% Republican advantage)
Dr. Caughey (per election average)	-.066 (6.6% Republican advantage)
Dr. Duchin (sum total)	-.8336

Dividing Dr. Duchin's efficiency gap score by 12 again converts a sum total into a per election average, consistent with the other experts' calculations:

Expert	**Efficiency Gap** (0 is most fair)
Dr. Barber (per election average)	-.025 (2.5% Republican advantage)
Dr. DeFord (per election average)	-.063 (6.3% Republican advantage)
Dr. Caughey (per election average)	-.066 (6.6% Republican advantage)
Dr. Duchin (per election average)	-.069 (6.9% Republican advantage)

That simple adjustment (dividing by 12) converts Dr. Duchin's total mean-median and total efficiency gap calculations to a format that is readily comparable to the other experts' analyses, belying the Special Master's conclusion that Dr. Duchin's mean-median difference and efficiency gap calculations were outliers. Indeed, these charts show that it is *Dr. Barber's* scores, not Dr. Duchin's, that are outliers.[31] *See infra* Section VI(E)(3).

[31] Among Dr. Duchin, Dr. DeFord, Dr. Rodden, and Dr. Caughey, the small discrepancies are easily accounted for by the slightly different timespan of elections under consideration.

As a final note, the legal conclusions section of the Special Master's Report fails to acknowledge Dr. Duchin's use of two other metrics, the total Eguia metric and total partisan bias calculation. The Report's overview of the "Plans Presented to the Parties and *Amicus* Participants" notes that Dr. Duchin computed the proposed plans' partisan fairness using each measure. Report at 82-83 (FF153, FF155, FF157), 123. Those calculations, identified above (*see* § V(B)(2) *supra*), resoundingly demonstrate the excellent partisan fairness of the Governor's Plan. But the Report includes no conclusion addressing the total Eguia metric and total partisan bias calculation. Because no expert rebutted these metrics or calculations, the Court should rely on them as further evidence that the Governor's Plan epitomizes partisan fairness.

In sum, the Governor respectfully submits that this Court should accept and give significant weight to all of Dr. Duchin's opinions and testimony.

2. <u>This Court Should Not Rely on the Opinion of Dr. Barber Because He Is Unqualified in the Area in Which He Opined, His Methodology Is Not Generally Accepted, and His Analysis Had Serious Flaws</u>

(a) Dr. Barber's Opinions Should Receive Little or No Weight Because He Was Unqualified to Give Them

Dr. Barber's testimony should garner little if any credit because he offered expert testimony that was beyond the scope of his special training and experience.

Accordingly, the Court should not credit the Special Master's reliance on his opinions.

The Special Master "credit[ed] the opinions and methodology of Dr. Barber" based on his status as "an associate professor of political science at Brigham Young University and faculty fellow at the Center for the Study of Elections and Democracy in Provo, Utah, who received his PhD in political science from Princeton University in 2014 with emphasis in American politics and quantitative methods/statistical analyses." Report at 165 (FF8).

But Dr. Barber was not offered as a general expert on political science or American politics. Rather, as shown by Dr. Barber's opening report, he was "asked by counsel to review [HB 2146] … and compare it to a set of simulated redistricting plans across a number of factors commonly considered in the redistricting process and in redistricting litigation." Barber Report at 3. To do this, Dr. Barber "implement[ed] a publicly available and peer-reviewed redistricting simulation algorithm to generate 50,000 simulated district maps, each containing 17 congressional districts." *Id.* Dr. Barber then "compare[d] the simulated plans against [HB 2146] using a number of commonly used redistricting criteria to assess whether [HB 2146] is consistent with what one would expect to see in a redistricting plan composed without reference to any racial or partisan considerations." *Id.*

Dr. Barber was not qualified to offer expert testimony on reapportionment and partisan influence in the redistricting process, nor was he qualified to use an algorithm to generate simulated redistricting maps. Dr. Barber has not published "on these particular topics," and his "academic work has not focused on redistricting." Tr. 561:17-25. Indeed, although Dr. Barber's CV boasts publications on many *other* topics, he has never been published "in the area of redistricting" at all, let alone on the subject of "partisan influence in the redistricting process." *Id*. at 562:4-12. Dr. Barber also agreed that none of his publications "involve[d] simulated redistricting analyses." *Id*. at 562:13-16. Additionally, Dr. Barber testified that prior to his work in Pennsylvania this year and the very recent North Carolina redistricting trial, Dr. Barber had never used "any algorithm to generate simulated district maps." *Id.* at 562:25-563:24; *see also id.* at 561:4-12. Nor was Dr. Barber involved in writing or testing the algorithm that he used. *Id.* at 512:15-22, 596:18-22.

"An expert may express his opinion only on matters which are within his or her scientific training and experience." *Commonwealth v. Crawford*, 364 A.2d 660, 664 (Pa. 1976) (citation omitted); *see also Steele*, 192 A.2d at 398 (affirming disqualification of expert who did not have experience doing the specific task at issue); *Wilson v. Woods*, 163 F.3d 935, 937 (5th Cir. 1999) (affirming disqualification of expert who has "recently shifted his professional emphasis" to

expertise for which he was offered). "The problem in this case is that the testimony was … beyond the range of the training, knowledge, intelligence, and experience of" Dr. Barber. *Crawford*, 364 A.2d at 664.

This Court would not be alone in concluding that Dr. Barber is unqualified to testify about the topics on which he opined. As noted, Dr. Barber testified that he had used his current methodology in only two other instances, each very recent. Tr. 561:4-12. One of those was to analyze the Pennsylvania state legislative plan under consideration by the Pennsylvania Legislative Reapportionment Commission ("LRC"). *Id.* Earlier this month, Professor Mark Nordenberg, Chair of the LRC, concluded that Dr. Barber was unqualified to use the very same methodology to analyze the state legislative plan: "When I reviewed the resume of the young faculty member called as an expert by the House Republican caucus, … what really caught my attention is that this academic expert has not published a single academic article in the areas for which his expert testimony was being presented."[32]

[32] Statement of Professor Nordenberg at 17-18, Meeting of the Pennsylvania Legislative Reapportionment Commission Approval of a Final Plan (Feb. 4, 2022) ("Nordenberg Statement") https://www.redistricting.state.pa.us/resources/Press/2022-02-04%20Chairmans%20Statement.pdf.

The Court can take judicial notice of Professor Nordenberg's statement as published on the LRC's state-run website. *See, e.g., In re Dawkins*, 98 A.3d 755, 759 (Pa. Commw. Ct. 2014) (taking judicial notice of Department of State website); *accord Hill v. Dept. of Corrections*, 64 A.3d 1159, 1165 n.3 (Pa. Commw. Ct. 2013) (taking judicial notice of Department of Corrections website); *Williams v. City of Philadelphia*, 188 A.3d 421, 439 n.5 (Pa. 2018)

Because Dr. Barber's testimony exceeded his qualifications and experience, his opinions should be afforded little or no credit.

(b) Dr. Barber's Testimony Should Receive Little or No Weight Because His Methodology Is Not Generally Accepted

Dr. Barber's testimony was also improper (or should receive little weight) for the independent reason that Dr. Barber's methodology has not "achieved 'general acceptance' in the relevant scientific community." *Blum ex rel. Blum v. Merrell Dow Pharm., Inc.*, 764 A.2d 1, 2 (Pa. 2000).

As Dr. Barber testified, he used a "sequential Monte Carlo analysis," which he described as "a very new algorithm," to create the maps he relied on for the simulation analysis he performed. Tr. 598:21-599:24. Dr. Barber conceded that this Sequential Monte Carlo ("SMC") analysis methodology is not yet peer-reviewed, *id.* at 599:25-600:10, and that the papers he cited in support of the analysis he used were in fact describing a *different methodology altogether*, the Markov Chain Monte Carlo ("MCMC") method, *id.* at 596:22-599:24. Because Dr. Barber's methodology has not been peer-reviewed and has not been adequately tested, it is not generally accepted.

(Wecht, J., dissenting) (taking judicial notice of Philadelphia City Council committee meeting transcripts available on council's website).

(c) Dr. Barber's Testimony Should Receive Little or No Weight Because of Significant Flaws in His Analysis

Beyond the fact that Dr. Barber is unqualified, and that his methodology is not generally accepted, Dr. Barber's execution of his methodology was also fundamentally flawed.

In Dr. Barber's opening report, he described his "methods" as follows:

> To gauge the degree to which the HB2146 plan is a partisan gerrymander, I conduct simulated districting analyses to allow me to produce a large number of districting plans that follow traditional redistricting criteria using small geographic units as building blocks for hypothetical legislative districts. This simulation process ignores all partisan and racial considerations when drawing districts. Instead, the computer simulations are programmed to create districting plans that follow traditional districting goals without paying attention to partisanship, race, the location of incumbent legislators, or other political factors. This set of simulated districts is helpful because it provides a set of maps to which we can compare the HB2146 map that also accounts for the geographic distribution of voters.

Barber Report at 11. Dr. Barber further agreed that to validly compare the proposed redistricting plans with a control set, he would need to create sample maps "under the same conditions" as the proposed plans being compared. Tr. 567:12-25. But as Dr. Barber conceded during his testimony, the map simulations he relied upon in forming his conclusions—*i.e.*, that were the entire basis for his opinions and testimony—were fundamentally dissimilar to the proposed redistricting plans at-issue in this case.

First, Dr. Barber testified that in his simulation set of maps, he allowed no more than one split municipality (Philadelphia), even though every one of the maps before the Court, including the HB 2146 map, splits *at least 16 municipalities*. *Id.* at 570:17-571:18; **Ex. 2**, Duchin Response Report at 2, Table 1.

Further, other experts testified that they were unable to confirm Dr. Barber's analysis. Dr. Duchin, for example, testified that "[s]ome of the expert reports provide you enough detail to see the results election by election.… [F]rom my review, it's my understanding in particular that Doctor Barber's reports do not." Tr. 367:13-22. "[I]t was much harder to audit and spot – check some of Doctor Barber's findings because there's so much averaging happening. But in the instances where I was able to, I found some clear errors of calculation." *Id.* at 368:12-18; *see also id.* at 446:6-447:14. Dr. Duchin explained: "[I]n a few cases where I was able to check an outcome, I think he may be systematically off by a seat [for Democrats or Republicans]. And when he's reporting his averages and making a big difference about 9/8 [Democratic seat advantage] versus 8/9, being off by a seat can really matter." *Id*. at 389:18-25.

Additionally, Dr. Barber's opening report demonstrates that he did not study elections individually, instead only using a blended or averaged election index with a non-standard methodology. Dr. Barber stated that he conducted his analysis using "all statewide [non-judicial] elections conducted between 2012 and 2020." Barber

Report at 15. This dataset consists of four contests from 2020, two from 2018, five from 2016, one from 2014, and five from 2012. *Id.* at 15 n.14; *see also* Tr. 588:5-8. This makes 17 elections in all. Whereas the common methodology in election analysis would be either to study the elections individually or to average them with equal weight, *see* Tr. 365:21-367:5, Dr. Barber instead summed the votes over all the elections, thereby giving far greater weight to the elections from years with a presidential contest, relative to midterm years, *see id.* at 586:19-591:5. Dr. Barber acknowledged this limitation of his methodology in his testimony, *id.*, and his reports cited no published work in political science or data science that uses this unconventional averaging methodology. This flawed methodology is another possible explanation for Dr. Barber's numbers so significantly diverging from those of other experts, (*see* § VI(B)(1), *supra*), and it adds to the many indications that his quantitative conclusions regarding "Democratic leaning seats" should be regarded as highly unreliable.

The Court should afford little weight to Dr. Barber's approach.

(d) Numerous Other Bodies Have Rejected or Discounted Similar Testimony from Dr. Barber

Other tribunals' skepticism of Dr. Barber's testimony further calls into question the Special Master's wholesale acceptance of his opinions.

Most telling is the criticism of Dr. Barber's methodology by Professor Nordenberg, Chair of the LRC. As noted above, Dr. Barber's analysis for the LRC

is one of the only instances in which he previously used the same algorithm that he used to form his opinions here, (*see* § VI(B)(2)(a) *supra*). Professor Nordenberg stated that in the LRC proceedings, the Commission also heard testimony from Professor Kosuke Imai, the Harvard professor who "actually developed the algorithm used by [Dr. Barber] to analyze" the LRC plan and proposed congressional redistricting plans.[33] According to Professor Nordenberg, when Professor Imai scrutinized Dr. Barber's conclusions about the LRC plan: "(1) [Professor Imai] could not replicate the results, which raises questions; [and] (2) when [Professor Imai] used the algorithm that he had developed to assess the preliminary plan himself, he found that plan to be less of a statistical outlier than the House Republicans [and Dr. Barber] had claimed[.]"[34] This criticism is particularly noteworthy because during Dr. Barber's testimony in this case, Dr. Barber pointed to Professor Imai's use of the algorithm in the LRC proceedings to demonstrate its reliability. *See* Tr. 663:8-23.[35] Professor Imai's rejection of Dr. Barber's findings in the LRC proceedings underscores that, even putting aside his choice of the algorithm itself, Dr. Barber's use of the algorithm is highly

[33] *See* note 33, *supra*, Nordenberg Statement at 18.

[34] *Id.*

[35] Due to a scrivener's error, the transcript of the evidentiary hearing in the Commonwealth Court incorrectly refer to Professor Imai as Khalif Ali; Khalif Ali is one of the amici in this case.

questionable and his results should not be regarded as reliable, especially when they conflict with the findings of the other experts, who are indisputably leaders in this area.

Other courts have reached similar conclusions discounting the reliability of Dr. Barber's analysis. In at least two other cases, Dr. Barber has testified, as he did here, about the effect of various states' political geography on apportionment. *See, e.g.*, *id.* at 506:15-509:9. Most recently, in *Adams v. DeWine*, --- N.E.3d ----, Nos. 2021-1428 and 2021-1449, 2022 WL 129092 (Oh. Jan. 14, 2022), the Ohio Supreme Court rejected Dr. Barber's political geography testimony, holding "that the body of petitioners' various expert evidence significantly outweighs the evidence offered by [Barber and the other respondents' experts] as to both sufficiency and credibility." *Id.* at *11. In other jurisdictions, the criticism of Dr. Barber has been even more pointed. In *Common Cause v. Lewis*, No. 18 CVS 014001, 2019 WL 4569584 (N.C. Super Ct. Sept. 3, 2019), again in the context of testimony about political geography, the court identified a litany of "shortcomings in Dr. Barber's analysis," and, as a result gave "little weight to his testimony." *Id.* at *94-95.[36]

[36] Dr. Barber also provided testimony in *Jones v. DeSantis*, 462 F. Supp. 3d 1196 (N.D. Fla. 2020), on a subject not related to his opinions in this case. (*Jones* was later reversed and vacated on grounds unrelated to Dr. Barber's testimony.) The district court's criticism of Dr. Barber's testimony is scathing. The court stated: "I do not credit the testimony. Indeed, one in

Given the many issues with Dr. Barber's qualifications and methodology, the Court should not credit his testimony.

3. This Court Should Not Rely on the Opinion of Dr. Keith Naughton Because He Lacks Sufficient Experience, Employed No Methodology, and Is Unfamiliar with the Legal Framework for Assessing Proposed Plans

The Special Master also erred in crediting the opinion of Dr. Keith Naughton, who testified on behalf of the Reschenthaler Intervenor-Respondents.

Dr. Naughton's opinions lack credibility and should be discounted because (1) he is a partisan political operative with no demonstrated experience in redistricting; (2) his opinion is just that—his own opinion—unsupported by any particular methodology, evidence, data analysis, or authority; and (3) he testified that has never read this Court's *League of Women Voters* precedential opinion from 2018, nor did he factor its mandate or guiding principles into the opinions he offered in this case.

First, as to his lack of relevant experience, Dr. Naughton testified that "much of [his] professional career has been dedicated to helping Republican candidates in Pennsylvania win their seats." Tr. 769:19-770:4; *see also* Report at 94 (FF218). Dr. Naughton conceded that he is not a mathematician; further, he agreed that his CV identifies "no particular experience in redistricting," and that he has never served

search of a textbook dismantling of unfounded expert testimony would look long and hard to find a better example than the cross-examination of this expert." *Id*. at 1246-47.

as an expert in redistricting litigation before. Tr. 777:17-778:9, 792:3-5; *see also* Report at 93 (FF215). As to his purported opinions on "the community interests undergirding the Free and Equal Elections Clause," Report at 94 (FF221), his testimony in no way established sufficient experience with or knowledge about each of the vast number of areas in Pennsylvania he testified about; accordingly, his claim to be able to speak to the desires of those communities should not be credited. *See, e.g.*, Tr. 690:11-22 (asserting only that Dr. Naughton has "been in all 67 counties," and has "experience in all 67 counties" during his 15 years of running campaigns for Republican candidates).

Second, Dr. Naughton agreed that his report "does not identify any particular methodology" that he used to arrive at his conclusions, and does not "cite any authority or particular evidence for [his] opinions." Tr. 779:12-21, 813:5-22; *see also* Report at 94 (FF219). Moreover, Dr. Naughton conceded that he provided no quantitative analysis of how any of the proposed plans perform on the neutral redistricting criteria. Tr. 792:13-22, *see also* Report at 94 (FF220). Dr. Naughton further testified that he did not "consider vote dilution in [his] analysis to reach the conclusions [he] reached." Tr. 861:13-16.

Third, considering his testimony that he has never read even a summary of the *LWV I* opinion, Dr. Naughton certainly did not factor its mandate or guiding principles into his assessment of the maps offered here. Specifically, Dr. Naughton

testified that while he "may have seen a citation to" the *LWV I* decision from 2018, he has never read the opinion or even a summary of it. *Id.* at 816:10-817:24. He further testified that he was not aware, even vaguely, that *LWV I* held that there were such things as unconstitutional gerrymanders, or had invalidated a map on that basis. *Id.* at 822:18-824:10. Even more problematically, in an article entitled "Gerrymandering Merry-Go Round" published in PA Townhall.com on February 14, 2018 (one week after the *LWV I* decision), Dr. Naughton wrote: "Those who shake their fists at gerrymandering and clog the courts with their lawsuits are really announcing their own rigidity and intellectual bankruptcy to the world."[37] Tr. 818:19-821:3.

Puzzlingly, despite these severe credibility issues, the Special Master appeared to give Dr. Naughton ***special*** credit based on his status as the sole non-mathematician or data scientist who testified at the hearing, finding that he provided a "unique" perspective. *See* Report at 94, FF220-21, FF225 (while Dr. Naughton "provided no quantitative analysis of how any of the proposed plans perform on the neutral redistricting criteria," his testimony was "unique in this regard as no other expert was offered to opine on the community interests

[37] The existence and timing of this article call into question the veracity of Dr. Naughton's testimony that he was wholly ignorant of *LWV I*. *See* Keith Naughton, *Gerrymandering Merry-Go-Round*, PA TownHall.com (Feb. 14, 2018), https://www.patownhall.com/gerrymandering-merry-go-round/.

undergirding the Free and Equal Elections Clause"). As explained above, however, his opinions lack any credible foundation—they are nothing more than *ipse dixit*—and should carry little, if any, weight with this Court. *Cf. Gen. Elec. Co. v. Joiner*, 522 U.S. 136, (1997) ("[N]othing in … the Federal Rules of Evidence requires a district court to admit opinion evidence that is connected to existing data only by the *ipse dixit* of the expert."); *accord Walsh Est. of Walsh v. BASF Corp.*, 234 A.3d 446, 466 (Pa. 2020) ("[W]e can agree with the United States Supreme Court that, in assessing the admissibility of an expert's testimony, a court should not turn a blind eye when an expert connects his method to his conclusion only by the because-I-said-so of his '*ipse dixit*[.]'").

4. The Special Master Erred by Discrediting the Report of Michael Lamb, Pittsburgh City Controller

The Special Master further erred in finding that the Declaration of Michael Lamb was not "particularly useful or credible." Report at 150 (FF13).

At the hearing, the Senate Democratic Intervenors submitted into evidence a report by Michael Lamb, the Pittsburgh City Controller. *See* Assessment of Reapportionment Plan as Submitted by Pennsylvania Senate Democratic Caucus as it relates to Pittsburgh and its Southern and Western Neighborhoods (Jan. 24, 2022) (the "Lamb Report"). Mr. Lamb's Report sets out his extensive professional and personal background and involvement in the Pittsburgh community, establishing that he (1) is currently the elected City Controller of Pittsburgh,

serving in his fourth term; (2) has lived in the south hills of Pittsburgh his whole life; (3) was previously elected county wide as the Allegheny County Prothonotary; and (4) previously worked in Pittsburgh City Council. *Id.* at 1. Mr. Lamb opines that splitting Pittsburgh into two different congressional districts is the best solution for long-established communities, citing "clear dissimilarities among the[] southern and western communities of interest and the rest of Pittsburgh." *Id.* at 1-2.

Yet the Special Master rejected Mr. Lamb's opinion in a single paragraph, finding his declaration "unpersuasive because it is based on Mr. Lamb's life and subjective **personal** experiences, which the Court does not find particularly useful or credible." Report at 150 (FF13) (emphasis in original). The Special Master further stated that Mr. Lamb "was not presented as an expert and his declaration does not address why it is absolutely necessary to split the City of Pittsburgh to achieve population equality in any congressional district."[38] *Id.* (FF13). Inconsistently, however, the Special Master found Dr. Naughton's testimony regarding communities of interest to be "credible" based on his "professional ***and personal*** experience." *Id.* at 154 (FF3) (emphasis added). Mr. Lamb's statements, which are undoubtedly based on both his personal and professional experience as

[38] As is explained in Section VI(C)(3)(b), *infra*, there is simply no requirement that each proposed plan address, for each political subdivision split, why it was "absolutely necessary" to do so to achieve population equality.

the elected Pittsburgh City Controller, are certainly more credible than Dr. Naughton's, given that Mr. Lamb opines exclusively about Pittsburgh communities, and his constituents consist *entirely* of Pittsburgh residents from *both* political parties as well as those unaffiliated with any party. Accordingly, the Court should credit the opinions provided by Mr. Lamb in the Lamb Report.

C. Exception Two – The Special Master Disqualified the Maps Least Likely to Cause Systematic Vote Dilution Due to a Fundamental Misunderstanding of the Free and Equal Elections Clause

1. District Maps Should Be Fair, Meaning That They Should Provide Voters an Equal Opportunity to Elect the Representatives of Their Choice, and They Should Not Entrench a Structural Partisan Advantage

The Special Master improperly placed a thumb on the scales in favor of plans that deliver a partisan advantage to one political party, out of misguided veneration of blindly drawn maps, couched as deference to Pennsylvania's purported "political geography." In assessing partisan fairness, the Report stressed the Special Master's view that the "natural state of political voting behavior and tendencies in the entirety of the Commonwealth" benefits Republican candidates. Report at 196-97 ¶ 39. The Report concluded that because the resultant "most typical outcome" in randomly drawn redistricting plans in Pennsylvania is Republican advantage, *id.* at 84 (FF166), any proposed plan that pursued partisan fairness in the face of Pennsylvania's "natural and undisputed Republican tilt" would be engaged in "a subspecies of unfair partisan gerrymandering." *Id.* at 197 ¶

40. Consequently, the Report gave less weight to any proposed redistricting plan that yielded what the Special Master called "partisan advantage to the Democratic Party" according to the plan's mean-median scores or efficiency gap scores. *Id.* at 197 ¶¶ 41-42.

This approach was victim to, as Dr. Duchin testified, "a frequent conceptual mistake that people make with ensemble analysis, and that mistake is that typical is best. If you were drawing plans and you looked at a range of compactness scores, you wouldn't want a typical compactness score, you'd want a good one. And the same princi[ple] is operative here" with partisan fairness." Tr. 379:10-19. Partisan fairness does not extol typicality; it ensures that elected representatives are responsive and accountable, and that all voters have an equal opportunity, to the greatest degree possible, to elect the candidates of their choice. *See* Tr. 449:21-450:16.

Even Dr. Barber, the expert for the Republican Legislative Intervenor-Respondents, conceded that a *fairer* map is better than a *typical* map. Posed with a colorful hypothetical in which "a million monkeys in front of typewriters…banged out two redistricting plans[,]" Dr. Barber was given a choice: ***Either*** (1) a plan that "looks a whole lot like the median plan, the middle plan, the average plan in [Dr. Barber's] simulation. So it's completely unbiased in that first sense, but it's very biased in the second sense in that it'll result in one party's voters getting a lot

fewer seats out of their votes than the other"; ***or*** (2) a plan that "does the opposite. They get rid of the bias that harms the voter, so the voters are treated equally but they've created an outlier compared to [Dr. Barber's] simulated maps." *Id.* 582:17-584:01, ***Dr. Barber, tellingly, chose the second, fairer map***: "[H]olding all other factors equal, and you have the choice between these two plans, then I think you could pick the one that was less biased." *Id.* at 585:20-24.

Nothing about Dr. Barber's admission that typical is not always best should be surprising. The Special Master's charge, as put succinctly by Dr. Duchin, was to "choose an excellent plan." *Id.* at 450:16. In reapportionment, as in literature,[39] fine art,[40] and science,[41] there is no rule "that requires that we pick the most typical." Tr. 450:14-15. Under mean-median scores, efficiency gap scores, and other comparable partisan fairness metrics, an ideally "fair" plan—a plan that provides no structural advantage to either party—will receive a score of zero. *Id.* at 369:3-371:24; *see also* **Ex. 1**, Duchin Report at 17 ("zero is ideal").Therefore, when analyzing partisan fairness metrics, the Special Master erred in focusing solely on

[39] *See Commonwealth v. Neely*, 561 A.2d 1, 2 (Pa. 1989) (quoting Shakespeare and Cervantes).

[40] *See Commonwealth v. Barnes Found.*, 159 A.2d 500, 501 (Pa. 1960) (identifying the works of "Renoir, Cezanne, Manet, Degas, Seurat, Rousseau, Picasso, [and] Matisse" as "treasures").

[41] *See Potter Title & Tr. Co. v. Knox*, 113 A.2d 549, 554 (Pa. 1955) (Musmanno, J., dissenting) (describing "the monumental truths" of "Sir Isaac Newton and Nicholas Copernicus").

whether the proposed plans have positive or negative scores (which the Special Master equated with Republican and Democratic advantage). Instead, to determine a proposed plan's fairness, the key is to assess the magnitude of each score, *i.e.*, how near it comes to a score of zero. Because the Special Master did not properly apply partisan fairness metrics, this Court should not adopt the Report's partisan fairness findings or conclusions.

2. The Special Master Overlooked that the Neutral Redistricting Criteria Are a Means to Ensuring Free and Equal Elections

In applying the *LWV I* neutral criteria, the Special Master employed an overly rigid approach that appears, at least at times, to have been more a process of elimination than an application of the principles animating the criteria, *i.e.*, ensuring Free and Equal Elections and avoiding "unfairly dilut[ing] the power of a particular group's vote for a congressional representative." 178 A.3d at 817. For example, the Report's analysis selectively focused on individual criteria, rather than holistically assessing how the plans fared across *all* criteria. *See generally* Report at 137-61. This approach risked allowing individual metrics to dominate, while overlooking that, as the parties' experts broadly agreed, reapportionment and line-drawing necessarily entail trade-offs.[42] At bottom, the Report lost sight of the

[42] *See* Tr. 94:25-95:13, 106:1-6 (Rodden); *id.* at 211:11-212:9, 215:17-216:9 (DeFord); *id.* at 338:6-18, 339:12-342:11 (Duchin); *id.* at 627:13-628:13 (Barber); *id.* at 764:25-765:13, 829:19-830:3 (Naughton).

fundamental purpose of the neutral criteria, which is to help ensure that equal opportunity is provided to individuals to translate their political preferences into representation. The true shibboleth of "Free and Equal Elections" is each voter's "equally effective power to select the representative of his or her choice." *LWV I*, 178 A.3d at 814.

3. The Special Master Improperly Applied the Criterion of Respecting Political Subdivision Boundaries

In particular, the Special Master committed a significant error by improperly elevating one of the *LWV I* neutral criteria—the principle of keeping political subdivisions together—over the others, and in an unmistakably selective way. Most notably, without justification or support in the law, the Special Master disqualified five plans, including the Governor's Plan, for dividing the city of Pittsburgh across two districts. *See* Report at 194-95 ¶¶ 26-30. (The Special Master also disqualified the Governor's Plan for dividing Bucks County across two districts, *id.* ¶ 31, which is discussed further below in Section VI(D)(1).)

The Special Master faulted the plans that proposed to divide Pittsburgh for (1) "fail[ing] to present any credible evidence as to why it was 'necessary' to split the second largest city in Pennsylvania in order to achieve equal population"; and (2) fail[ing to] preserve the shared interest of the communities in the Pittsburgh area and the distinctive cultural fabric that has been shaped and formed within the city's limits." Report at 194-95 ¶¶ 27, 29, 30. Inconsistently, the Special Master

applied stringent and legally unfounded standards to these particular splits without imposing the same requirements on ***any split in any of other proposed plans***—including any of the 15 county splits or 19 municipality splits in HB 2146.

(a) Contrary to the Implication of the Special Master's Report, Redistricting Plans Are Not Required to Justify Every Split and Cannot Be Required to Preserve Every Community of Interest

There is simply no legal basis for the Special Master's decision to disqualify proposed plans for dividing a specific alleged community of interest or for failing to expressly justify each proposed split with a community-of-interest analysis. As almost all testifying experts recognized, there are inherent trade-offs involved among the traditional criteria when drawing a map, countless ways to satisfy the neutral redistricting criteria in a proposed plan, and no possibility of a "perfect" or "best" map:

- **Dr. Rodden** testified that "in general the idea is to not split these jurisdictions, but there are trade-offs between different jurisdictions," and noted "an example of a place where there's a trade-off where an redistricting expert has to face, between – between splits in different places and also involving compactness." Tr. 94:25-95:3, 106:1-6.

- **Dr. DeFord** testified that "in redistricting there's lots of examples of potential trade-offs between the metrics and between the criteria. And in a situation like this one where many of the plans are preserving lots of political boundaries, the compactness measures that are measuring sort of the external perimeters of those boundaries are to a large extent sort of controlled by the municipal boundaries themselves, because they [con]form the outer boundaries of the districts. And so given that, there can be some tension between these, depending on the shapes of the municipal boundaries

that are preserved." *Id.* at 215:17-216:9; *see also* Report at 70 (FF81).

- **Dr. Duchin** testified: "We've heard people talking today about absolute[] minimization of these numbers, and to that I would just remind you it's minimization in view of … the other properties and criteria that must be maintained. So everyone who thinks about these numbers understands that there are trade-offs, and that perhaps if you split one more county you can get a better compactness score and so on. So these all reflect decisions about those trade offs." Tr. 338:6-18; *see also* Report at 78 (FF131).

Indeed, on this point, even Dr. Barber and Dr. Naughton agreed with the consensus. *See* Tr. 627:13-628:13; *see also* Report at 93 (FF213); Tr. 765:10-766:22, 829:19-830:3; *see also* Report at 97 (FF236).

Relatedly, no individual neutral redistricting criterion, such as respecting political subdivision boundaries—let alone the preservation of one particular community of interest—should be pursued at all costs, no matter the effect on the plan as a whole. As Dr. Duchin testified, splitting a particular political subdivision among congressional districts can sometimes be viewed as a positive factor by the relevant communities. She provided the example of a New York redistricting plan that made a change to keep Buffalo together in one congressional district, which was criticized based on the fact that Buffalo would therefore lose a representative. *See* Tr. 339:15-341:21.

Moreover, no party or amicus in this case satisfies the "justify all splits" standard fashioned by the Special Master. For example, HB 2146 splits

Washington County, without explanation or justification (something that Governor Wolf's Plan does not do). As the Governor explained, his proposed District 13

> combines the major energy-producing counties of Washington, Greene, Fayette, Somerset and Westmoreland into one compact district in the southwest with their shared industries of gas exploration and mining. The district unites businesses and families of the Mon Valley communities—with common interests and history with communities to the east and west.

Gov. Opening Br. at 16 (Jan. 24, 2022). HB 2146, by splitting Washington County and combining it with Beaver County and Allegheny County, separated Washington County's community of interest and forced it together with less similar communities, ignoring the "clear line of demarcation between Beaver County and Washington County" that the Governor identified when reviewing public submissions in preparing his proposed map. *Id.* at 17.

(b) The Special Master Misconstrued the Direction to Avoid Splits Except Where "Necessary to Ensure Equality of Population"

The Special Master also erred by misconstruing—and then inconsistently applying—language from *LWV I* cautioning against "divid[ing] any county, city, incorporated town, borough, township, or ward, except where necessary to ensure equality of population." *LWV I*, 178 A.3d at 816-17; *see also* Report at 24. Under the Special Master's interpretation, the only relevant criteria would be equality of population and the number of split divisions, and the only permissible maps would be those that achieved the absolute mathematical minimum of splits consistent with

population equality. But under that view, none of the proposed plans in this case—including HB 2146—is compliant (nor would be the 2018 Remedial Plan adopted by this Court in *LWV II*).

Illustrating this very point is the report of Dr. John H. Memmi, which was submitted by the Senate Republican Legislative Intervenor-Respondents. The Special Master cited Dr. Memmi's report for the proposition that "splits are only necessary when the total population of a [political subdivision] is greater than one district." Report at 103 (FF271) (citing Memmi Report at 3). The implication of that proposition, as reflected in Dr. Memmi's report, is that the only political subdivisions that may be split in a proposed plan are Philadelphia, Allegheny, and Montgomery Counties (as the only political subdivisions with populations larger than the total population of Pennsylvania divided equally into 17 districts). Memmi Report at 3. But HB 2146 splits 15 counties out of 67, and 19 municipalities out of out of 2,572 (including 3 split by county lines). *See* Memmi Report at 3; *see also* **Ex. 1**, Duchin Report at 8, Table 2. According to the Special Master's reasoning, the majority of those splits are not "necessary to ensure equal population." Indeed, the Republican Legislative Intervenor-Respondents made no such assertions of necessity.

In fact, each map proponent in this case understood the legal framework regarding splits in essentially the same way; each endeavored to keep split

numbers low while balancing splits against the other criteria. Disregarding the propriety of that approach, the Special Master adopted an overly rigid interpretation of *LWV I*'s "except where necessary" language and then employed that interpretation inconsistently, using it to disqualify only the maps that split Pittsburgh or Bucks County. But, as described above, HB 2146 splits Washington County and the Governor's Plan does not; this demonstrates that splitting Washington County is not necessary to achieve equal population.

On all fronts, the Special Master misapplied the "maintaining political subdivisions" criterion, exalting it over the other neutral criteria and haphazardly imposing a burden of justification for some, but not all, splits, none of which finds support in the Pennsylvania Constitution or *LWV I*.

D. Exception Three – The Special Master Improperly Disqualified the Governor's Plan

1. As With Its Treatment of Pittsburgh, the Special Master's Report Erred in Criticizing the Governor's Plan for Splitting Bucks County

The Special Master erred in disqualifying the Governor's Map based on the fact that it divides Bucks County between two congressional districts. *See* Report at 195 ¶ 31, 200. First, this was error for all the same reasons discussed above regarding Pittsburgh (*see* § VI(C)(3), *supra*). Second, even assuming that the Governor *was* required to specifically justify each decision regarding political subdivision splits (though he was not), he did so as to Bucks County. The

Governor explained the line-drawing decisions evidenced in his map, including regarding Bucks County, and the efforts made to preserve relevant communities of interest:

> District 1 — Greater Bucks County: Includes all communities of Bucks County outside of those immediately adjacent to Northeast Philadelphia and connects them with similar communities in Montgomery County. These communities include similar economic traits and are experiencing increased population. This district in Montgomery County has grown slightly to adjust for needed population in Bucks County. Numerous comments on the Redistricting Public Comment Portal noted that Bucks County is a swing district and that it should continue to maintain its competitiveness. The minimal shifts in the boundaries of District 1 will continue to make it a competitive district going forward.

Gov. Wolf's Brief in Support of Proposed 17-District Congressional Redistricting Plan at 12-13 (Jan. 24, 2022). Yet rather than credit the Governor's reasoned decision-making, the Special Master relied *only* on Dr. Naughton's conclusory and unsupported statements that Bucks County should be entirely within one district to conclude that the Governor's Plan embodied improper partisan motivations. *See, e.g.*, Report at 157-58 (FF 15-16) (quoting Dr. Naughton's opinion that "[t]he right Bucks County district would have Bucks in its entirety"). The Special Master's Report did not adequately justify its decision to afford "great weight" to Dr. Naughton's baseless opinions about Bucks County (*see* Report at 195 ¶ 31) while failing to acknowledge the reasoned explanation offered by the Governor.

2. There Is No Evidence Supporting the Special Master's Finding that the Governor's Plan Splits Pittsburgh "Solely for Partisan Gain"

While the Special Master disqualified five of the 13 proposed plans for splitting Pittsburgh, the Special Master singled out the Governor's Plan as the only proposed plan it found to split Pittsburgh "***solely for partisan gain*** by creating another Democratic district." Report at 200 (emphasis added).[43] But such a finding as to the subjective motivations behind this particular decision made in drawing the Governor's Plan lacks any evidentiary support in the record, and should not be credited by this Court.

The Governor has explained the rationales behind the make-up of the various districts proposed in the plan, including how they minimize splits while preserving communities of interest. *See* Gov. Wolf's Brief in Support of Proposed Plan at 12-18 (Jan. 24, 2022). Regarding Districts 16 and 17 (which each contain a portion of Pittsburgh), the Governor noted, for example, that (1) proposed District 16 is "[r]ich with a history in manufacturing along the Ohio River and throughout the region" and is "transforming with smaller manufacturing and service

[43] *Compare with id.* at 201 (concluding the Draw the Lines Plan split Pittsburgh "without any convincing or credible expert explanation as to why this was absolutely necessary to achieve population equality or to refute other expert opinions that the City of Pittsburgh does not need to be split in order to achieve population equality between districts") and *id.* at 202 (concluding the Senate Democratic Caucus Plans split Pittsburgh "in order to create another Democratic congressional district ***which appears to be*** solely for partisan gain by creating another Democratic district") (emphasis added).

industries"; and (2) proposed District 17 "recognizes the decades-long economic connection of these communities and the area's evolving technology sector along with strong educational and medical institutions." *Id.* at 17-18.

Pittsburgh City Controller Lamb's Report gives further credence to the decision of the Governor's Plan to split Pittsburgh. The Lamb Report demonstrates that there are *various* communities of interest within Pittsburgh, and that splitting Pittsburgh into two districts is the best solution for long-established communities due to "clear dissimilarities among the[] southern and western communities of interest and the rest of Pittsburgh." Lamb Report at 1-2. (As explained above, the Special Master erred in finding this declaration not to be "useful or credible," (*see* § VI(B)(4), *supra*).)

It appears that the sole basis for the Special Master's "finding" regarding the Governor's Plan's treatment of Pittsburgh is the unsupported opinions of Dr. Barber and Dr. Naughton, the former opining, without any support, that Pittsburgh need not and should not be divided (and that any decision otherwise is suspect). *See* Report at 91 (FF 205-06) (citing Barber testimony and Barber Rebuttal Report at 8, Table 1, 23); *see* Barber Rebuttal Report at 22-23 ("Six of the plans . . . subvert the non-partisan criteria to avoid municipal splits unnecessarily by intentionally dividing Pittsburgh for partisan gain."); Report at 155 (FF5) (crediting Dr. Naughton's opinion that Pittsburgh should be in one congressional

district). Notably, Dr. Barber undermined these very opinions that Pittsburgh should not be split by acknowledging that keeping Pittsburgh whole could be viewed as "packing . . . clearly gerrymandering." Tr. 627:13-628-22 (further acknowledging that "these cracking and packing concepts can occur intentionally or by accident," and "with ill-will or not ill-will"). For these reasons, and as set forth above, the Special Master erred in crediting Dr. Barber's and Dr. Naughton's unsupported (and self-contradictory) statements—without acknowledging the Governor's explanations to the contrary—as grounds for its finding that the Governor's Plan divides Pittsburgh "solely for partisan gain." Report at 200.

3. The Special Master Erred in Determining that the Governor's Plan's Compactness Was "Compromised"

The Special Master erred in concluding that, because Dr. Duchin acknowledged that the erratic municipal boundary of Pittsburgh might lower the compactness of a whole-Pittsburgh district, the Governor's Plan's compactness scores were thus "compromise[d]" and "not comparable to other maps" that did not split Pittsburgh. *See* Report at 148 (FF4, CL). As previously noted, (*see supra* § VI(C)(3)(a)), all experts in this action recognized that map-drawing inherently involves trade-offs among the redistricting criteria, including between the criteria

of minimizing political subdivision splits and maintaining compactness.[44] And that was all that Dr. Duchin acknowledged—that the splitting of Pittsburgh was "one of the many factors that contribute[d] to" the high compactness score of the Governor's Plan. Tr. 436:3-9. The Special Master erred in finding that the Governor's Plan's high compactness scores were "compromised" simply because they were, of course, affected by the countless trade-offs among the traditional redistricting criteria necessarily involved in any map-drawing process.

E. Exception Four – The Special Master Erred in Recommending the HB 2146 Plan, and This Court Should Not Adopt It

1. HB 2146 Should Not Have Been and Is Not Entitled to Any Presumption of Reasonableness or Legitimacy

Although the Special Master's Report initially purported to reject the Republican Legislative Intervenor-Respondents' request that the Special Master "provide some degree of presumptive deference to HB 2146," Report at 208 ¶ 61, the Report ultimately treated HB 2146 as "presumptively reasonable and legitimate," *id.* at 213 ¶¶ 89-90. This was clear error.

First, the conclusion that HB 2146 is presumptively reasonable was premised on incorrect findings of fact. The Report mischaracterizes Governor Wolf's veto of HB 2146 as lacking "any cognizable legal objection to the

[44] *See* Tr. 94:25-95:13, 106:1-6 (Rodden); *id.* at 211:11-212:9, 215:17-216:9 (DeFord); *id.* at 338:6-18, 339:12-342:11 (Duchin); *id.* at 627:13-628:13 (Barber); *id.* at 764:25-765:13, 829:19-830:3 (Naughton).

constitutionality of the congressional districts contained therein." *Id.* at 213 ¶ 91. But as the Governor explained, HB 2146 was fundamentally unfair to Pennsylvania voters:

> This legislation fails the test of fundamental fairness. The result of a partisan political process, HB 2146 does not deliver on the Pennsylvania Constitution's guarantee of free and equal elections. The people of Pennsylvania deserve a fair election map that promotes accountability and responsiveness to voters and is drawn in an open and honest way. Instead, HB 2146 adopts a map selected by politicians to take advantage of the process and choose their own voters. This directly contravenes a "core principle of our republican form of government" identified by the Pennsylvania Supreme Court: "that the voters should choose their representatives, not the other way around." *League of Women Voters v. Commonwealth*, 178 A.3d 737, 740-41 (Pa. 2018).[45]

As shown below, (*see infra* § VI(E)(2)-(3)), the Governor's objections to HB 2146 were well-founded. Not only is HB 2146 an unfair redistricting plan, it is the one of the most unfair plans—if not *the most* unfair plan—of all the plans submitted to this Court, (*see infra* § (VI)(E)(3)). Accordingly, as a factual matter, it was unreasonable for the Special Master to disregard the Governor's veto to apply a presumption in favor of HB 2146.

[45] Veto Message, Office of the Governor of the Commonwealth of Pennsylvania (Jan. 26, 2022), https://www.governor.pa.gov/wp-content/uploads/2022/01/20220126-HB-2146-Veto-Message.pdf; *accord, e.g.*, Letter from Governor Tom Wolf to Speaker and Majority Leader of Pennsylvania House of Representatives (Dec. 28, 2021), https://www.governor.pa.gov/wp-content/uploads/2021/12/12.28.21-TWW-Cutler-Benninghoff-HB-2146-Final.pdf.

Second, as a matter of law, state supreme courts and the U.S. Supreme Court have flatly rejected the presumption applied by the Special Master.

Most importantly, the U.S. Supreme Court has stated that a legislature's vetoed reapportionment plan does not warrant anything more than "thoughtful consideration[.]" *Sixty-Seventh Minnesota State Sen. v. Beens*, 406 U.S. 187, 197 (1972) (distinguishing between "the *State's* policy" on districting, on the one hand, and the legislature's vetoed reapportionment plan, on the other hand, which "represented *only* the legislature's proffered current policy." (emphasis added)).

Just months ago, in November 2021, the Wisconsin Supreme Court also expressly dismissed the argument that vetoed reapportionment plans receive special weight or consideration: "The legislature asks us to use the maps it passed during this redistricting cycle as a starting point, characterizing them as an expression of 'the policies and preferences of the State[.]' The legislature's argument fails because the recent legislation did not survive the political process." *Johnson v. Wisconsin Elections Commn.*, 967 N.W.2d 469, 490 n.8 (Wis. 2021) (internal citation omitted). Other state high courts agree. *See, e.g., Hartung v. Bradbury*, 33 P.3d 972, 979 (Or. 2001) (rejecting argument that Oregon Secretary of State, who as matter of statute conducts reapportionment after impasse between legislature and governor, "should have deferred to the Legislative Assembly's plan of reapportionment, even though the Governor vetoed that plan"); *Wilson v. Eu*,

823 P.2d 545, 576 (Cal. 1992) (rejecting argument that "special deference be given to the various plans passed by the Legislature but vetoed by the Governor").

Additionally, *Carstens v. Lamm*, 543 F. Supp. 68 (D. Colo. 1982), which factored heavily in Judge Craig's Findings, Recommended Decision, and Form of Order in *Mellow*,[46] refused to employ the approach followed by the Special Master here:

> Both the Governor and the General Assembly are integral and indispensable parts of the legislative process. To take the [Special Master's] position to its logical conclusion, a partisan state legislature could simply pass any bill it wanted, wait for a gubernatorial veto, file suit on the issue and have the Court defer to their proposal. This Court will not override the Governor's veto when the General Assembly did not do so.

543 F. Supp. at 79; *accord O'Sullivan v. Brier*, 540 F. Supp. 1200, 1202 (D. Kan. 1982) ("[W]e are not required to defer to any plan that has not survived the full legislative process to become law." (citing *Beens*, 406 U.S. at 197)).

Without citation or reference to the overwhelming weight of authority, the Special Master relied primarily on *Upham v. Seamon*, 456 U.S. 37 (1982), which is easily distinguishable and does not support the proposition espoused by the Special Master. In *Upham*, the U.S. Supreme Court reviewed a three-judge panel's decision invalidating a *lawfully enacted* redistricting plan and drafting its own plan. *Id.* at 38. Thus, *Upham*, unlike this case, involved a *fully-enacted plan* that

[46] *See Mellow*, 607 A.2d at 208 n.1; *see also id.* at 215, 219.

was *not vetoed by the Governor*. *See id.* ("Senate Bill No. 1 (SB1), was enacted on August 14, 1981."). Contrary to the conclusion of the Special Master, vetoed HB 2146 plainly does not represent "the policies and preference" of the Commonwealth of Pennsylvania. Report at 214-16 ¶¶ 93-97.

Indeed, where, as in Pennsylvania, a governor has the authority under the state constitution to veto redistricting plans, the U.S. Supreme Court has concluded that, under the U.S. Constitution's Elections Clause, "legislative action in districting the state for congressional elections shall be subject to the veto power of the Governor as in other cases of the exercise of the lawmaking power." *Smiley v. Holm*, 285 U.S. 355, 373 (1932). The Court reaffirmed *Smiley* in *Arizona State Legis. v. Arizona Independent Redistricting Commission*, 576 U.S. 787 (2015): "'[T]he Legislature' [as that term is used in the Elections Clause] comprises … the Governor's veto in the context of regulating congressional elections." *Id.* at 808 (quoting *Smiley*, 285 U.S. at 373).

Accordingly, HB 2146 "cannot be sustained by virtue of any authority conferred by the Federal Constitution upon the Legislature … to create congressional districts independently of the participation of the Governor as required by the state Constitution with respect to the enactment of laws." *Smiley*,

285 U.S. 373. As a matter of law, HB 2146 was not and is not entitled to any presumption of reasonableness or legitimacy.[47]

2. The Special Master Should Have Eliminated HB 2146 Based on the Traditional Redistricting Principles

The Special Master should have removed HB 2146 from consideration when applying the traditional redistricting principles, because it is literally dominated by other maps, as shown in Table 1 below:

Table 1: Comparison of compactness and splitting metrics.

name	mean Polsby	mean Schwartz	mean Reock	mean ConvHull	mean PopPoly	cut edges	split counties	county pieces	split munis	muni pieces
GovPlan	0.3808	1.6534	0.4313	0.8257	0.7834	5185	16	35	18	37
CitizensPlan	0.3785	1.6625	0.4512	0.8120	0.7725	5237	14	30	16	33
HB-2146	0.3212	1.8197	0.4087	0.7987	0.7524	5907	15	33	16	34
Carter	0.3214	1.8103	0.4499	0.7922	0.7416	5926	14	31	20	41
Gressman/GMS	0.3478	1.7351	0.4261	0.8176	0.7582	5582	15	32	16	33
HouseDemCaucus	0.2787	1.9693	0.4286	0.7717	0.7205	6853	16	34	18	37
SenateDemCaucus1	0.3147	1.8144	0.4137	0.7918	0.7519	6047	17	36	19	39
SenateDemCaucus2	0.3346	1.7478	0.4146	0.8153	0.7601	5505	16	34	16	33
Reschenthaler1	0.3629	1.6859	0.4347	0.8238	0.7737	5090	13	29	16	33
Reschenthaler2	0.3524	1.7127	0.4231	0.8161	0.7658	5237	13	29	16	33
CitizenVoters	0.3490	1.7133	0.4412	0.8082	0.7575	5173	14	31	16	33
VotersOfPA	0.3965	1.6069	0.4697	0.8209	0.7681	5052	15	31	18	37
KhalifAli	0.3523	1.7204	0.4448	0.8111	0.7456	5266	16	35	18	37

Ex. 2, Duchin Response Report at 2, Table 1. HB 2146 is dominated (*i.e.*, worse or equal on all metrics measuring compactness and splitting) when compared, for example, to the Citizens/Draw the Lines Plan. That alone should have been sufficient to remove HB 2146 from consideration.

[47] To the extent the Court finds that HB 2146 is entitled to some deference, the Governor's Plan—submitted by a coequal branch of government that is an equally "integral and indispensable part[] of the legislative process"—is entitled to the same deference. *Carstens*, 543 F. Supp. at 79 (explaining that the map passed by the legislative branch "cannot represent current state policy any more than the Governor's proposal," and that the Court "regarded the plans submitted by both the Legislature and the Governor as 'proffered current [state] policy'").

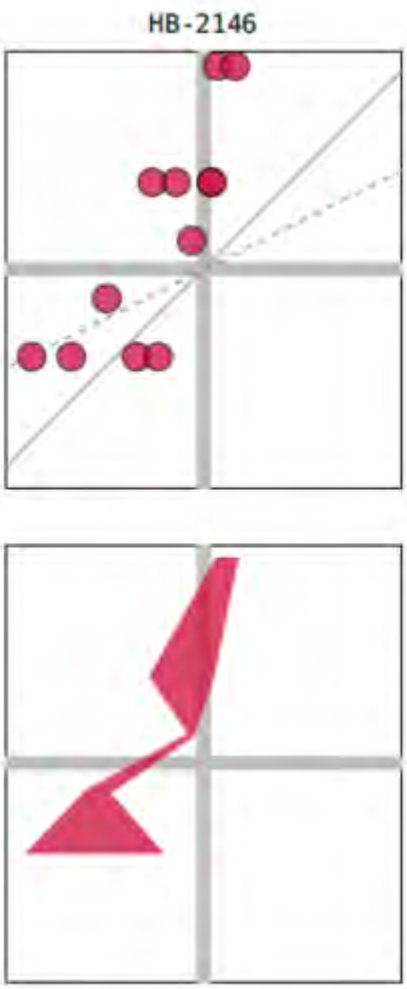
3. The Special Master Erred in Finding That HB 2146 Achieves Partisan Fairness

The Special Master erred in concluding that HB 2146 exhibits partisan fairness, in reliance on Dr. Barber's opinions that HB 2146 is more Democratic-leaning than a typical computer-drawn map. *See* Report at 191 ¶ 12, 211 ¶¶ 78-79; *see also id.* at 88 (FF188).

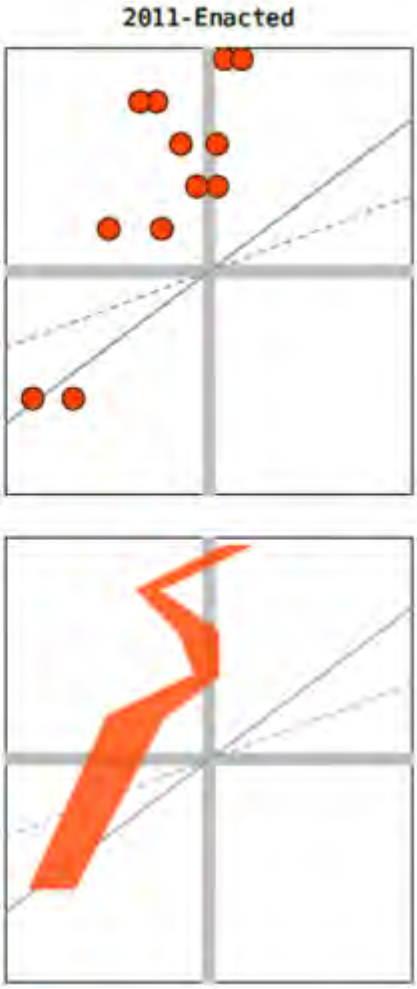
First, the Special Master improperly accepted Dr. Barber's invitation to assess HB 2146's partisan fairness in comparison to "typical" maps—*i.e.*, Dr. Barber's ensemble of blindly drawn, computer-generated maps. Rather, as explained by Dr. Duchin, the proper (and broadly accepted) barometers for partisan fairness are (1) a holistic consideration of whether a plan upholds Close-Votes-Close-Seats and allows majority preferences to typically secure majority representation; and (2) supporting evidence from simplified partisan fairness metrics, including the efficiency gap and mean-median scores cited approvingly by this Court in *LWV I*, 178 A.3d at 820, which aim to identify neutral maps that do not entrench a structural advantage in favor of any political party. Tr. 351:1-354:4, 369:11-371:1.[48]

[48] *See also* Tr. 383:17-23 (Dr. Duchin testifying: "I would caution against the conceptual mistake that typical is necessarily fair. Blind is not necessarily fair. Sometimes we have a benchmark such as with compactness. You want to be more compact. And I think with fairness, you want to be more fair.").

Second, the Special Master erred in failing to discuss the big picture of whether close votes tend to be converted to close seats under a given redistricting plan. But as Dr. Duchin's opening report shows, *see* **Ex. 1**, Duchin Report at 16, the voting patterns in every single one of the closest statewide races since 2014 would be converted by HB 2146 into a Republican majority in the Congressional delegation. Indeed, when comparing HB 2146 to the 2011 Plan that this Court rejected as "an unconstitutional partisan gerrymander," *LWV I*, 178 A.3d at 741, the two plans perform remarkably similarly in their conversion of close seats to a Republican majority. (In the below figures, the top left quadrant reflects more Democratic votes but more Republican Seats; the bottom right quadrant reflects more Republican votes but more Democratic seats. *See* **Ex. 1**, Duchin Report at 14.)



Ex. 1, Duchin Report at 16



Ex. 1, Duchin Report at 15

Third, the Special Master erred by relying on the partisan fairness scores for HB 2146 offered by Dr. Barber. *See* Report at 212 ¶¶ 82-83; *see also id.* at 89-90 (FF192-95). As stated above, those scores are not reliable, as they are conspicuous outliers when compared to Dr. DeFord's, Dr. Rodden's, Dr. Caughey's, and Dr. Duchin's mean-median and efficiency gap calculations, (s*ee* § VI(B)(1), *supra*). As a result, the partisan metric scores Dr. Barber assigned to HB 2146 should be, at a minimum, significantly discounted, if not outright rejected.

Fourth, Dr. Barber's prediction that HB 2146 will result "in 9 Democratic-leaning seats and 8 Republican-leaning seats" (Report at 88-89)—treated by the Special Master as "credible evidence of record" (*id.* at 211 ¶ 78)—is simply not sound. Indeed, Dr. Duchin's analysis confirms that HB 2146's total mean-median and total efficiency gap scores are in fact more biased toward *Republicans* than the mean of her 100,000 ensemble of computer-generated maps, not "more favorable to Democrats" as Dr. Barber contends (*id.*). *See* **Ex. 2**, Duchin Response Report at 4, Table 3 (reflecting negative total mean-median and efficiency gap scores for HB 2146 that are farther from zero, and thus even more biased towards Republicans, than the ensemble mean); *see also* **Ex. 1**, Duchin Report at 18-19, Figures 7 and 8 (showing that HB 2146 is typically more Republican favoring than most blind maps across many elections).

When assessing mean-median score and efficiency gap metrics, it is crucial to understand that the *closer a partisan fairness score is to zero* (whether positive and thus Democrat-favoring, or negative and thus Republican-favoring), the *more fair and less biased the plan*. *See* **Ex. 1**, Duchin Report at 17; Barber Report at 27-34; DeFord Report at 33. As a result, to determine whether HB 2146 displays partisan fairness, the Special Master should have examined how closely HB 2146's partisan fairness metric scores were to *zero* in comparison with the other proposed plans.

As shown by Dr. Duchin's analysis, among the 13 plans presented to the Court, HB 2146 consistently ranks as the ***most biased plan or one of the three most biased plans*** on the four partisan metrics employed to measure the partisan fairness of the proposed plans:

- Efficiency gap score – ***11th of 13***;
- Total Eguia metric score – ***11th of 13***;
- Total mean-median score – ***13th of 13***;
- Total partisan bias score – ***13th of 13***.

Ex. 2, Duchin Response Report; *see also* **Ex. 1**, Duchin Report at 17 (describing various partisan fairness metrics).

The other experts were in agreement. Dr. DeFord, the expert for the Gressman Petitioners, and Dr. Caughey, the expert for the Senate Democratic Caucus Intervenor-Respondents, ***likewise found that HB 2146 performs at the bottom of the pack according to partisan fairness metrics***.[49] Indeed, on cross-examination, Dr. Barber himself conceded that all plans other the Reschenthaler plans have mean-median scores closer to zero and are thus less biased than HB 2146. Tr. 577:18-578:22; *see also* Report at 92 (FF211).

[49] *See* DeFord Response Report at 15; Caughey Response Report at 22, Table 6.

Worse still, even applying the Special Master's own flawed "typicality is best" standard, HB 2146 is the *only* proposed plan that is more biased than a typical blindly drawn map across all partisan fairness metrics. *See* **Ex. 2**, Duchin Response Report at 4, Table 3 (reflecting that HB 2146 is the only proposed plan with partisan fairness scores that are in all instances farther from zero, and thus more biased, than the ensemble mean).

Because the Special Master's finding that HB 2146 reflects partisan fairness is based on (1) a misunderstanding of how partisan fairness may reliably be assessed; and (2) outlier partisan fairness scores and inaccurate data, it should be rejected by this Court.

F. Exception Five – The Election Calendar Should Be Modified in Accordance with Respondents' Submission

The Governor respectfully incorporates by reference Respondents' Exceptions Regarding the Special Master's Proposed Revision to the 2022 Election Calendar/Schedule.

VII. CONCLUSION

For the foregoing reasons, the Governor respectfully requests that the Court (1) decline to follow the Special Master's recommendation that the Court adopt the HB 2146 Plan; (2) instead, select the Governor's Plan, or, alternatively, another plan that both satisfies the traditional redistricting criteria and provides all

Pennsylvanians an equal opportunity to elect the representatives of their choice; and (3) modify the election calendar in accordance with Respondents' submission.

Respectfully submitted,

HANGLEY ARONCHICK SEGAL PUDLIN & SCHILLER

Dated: February 14, 2022

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CERTIFICATION

Public Access Policy. I certify that this filing complies with the provisions of the Public Access Policy of the Unified Judicial System of Pennsylvania: Case Records of the Appellate and Trial Courts that require filing confidential information and documents differently than non-confidential information and documents.

/s/ *Robert A. Wiygul*
Robert A. Wiygul

Exhibit 1

Comparison of Congressional Districting Plans in Pennsylvania

Moon Duchin
Professor of Mathematics, Tufts
University Senior Fellow, Tisch College of Civic Life

January 24, 2022

Comparison of Congressional Districting Plans in Pennsylvania

Moon Duchin
Professor of Mathematics, Tufts University
Senior Fellow, Tisch College of Civic Life

January 24, 2022

1 Assignment and qualifications

I am a Professor of Mathematics and a Senior Fellow in the Jonathan M. Tisch College of Civic Life at Tufts University. At Tisch College, I am the principal investigator of an interdisciplinary research lab focused on geometric and computational aspects of redistricting. I was recently awarded a major grant from the National Science Foundation to study *Network Science of Census Data*. My areas of research and teaching include the structure of census data, the design and implementation of randomized algorithms for generating districting plans, and the analysis of partisan fairness and of redistricting more broadly.

I was asked to evaluate several maps that have been proposed as alternatives for Congressional redistricting in Pennsylvania, and particularly to compare them in terms of traditional districting principles and partisan fairness.

I personally conducted all work in this report, supported by research assistants working under my direct supervision. A full copy of my CV is attached to this report.

1.1 Materials

- The largest single source of data is the U.S. Census Bureau. I principally use the Decennial Census release, together with supporting data products like the American Community Survey and the TIGER/Line geographical shapefiles. I have also made use of the datasets released by the Pennsylvania Legislative Reapportionment Commission at `redistricting.state.pa.us/maps/#census`.
- Language governing the guidelines for Congressional redistricting was drawn from the published principles of the Pennsylvania Redistricting Advisory Council [3].
- I extensively consulted the Court Order and the majority opinion from the 2018 case *LWV vs. Pennsylvania* [2, 1].
- I compared districting plans defined by block equivalency files. The Governor's plan is publicly posted at `portal.pennsylvania-mapping.org/plans`; the Citizens' Plan is posted at `drawthelinespa.org/pa-citizens-map`; and the data for `HB-2146` was provided to me by counsel.

2 Executive summary

In 2018, the Pennsylvania Supreme Court described four "neutral criteria" that collectively "provide a 'floor' of protection for an individual against the dilution of his or her vote": population balance, contiguity, compactness, and respect for political boundaries [1]. This gives initial points of comparison for the plans discussed in this report. The Congressional districting plan passed by the Pennsylvania House of Representatives (`HB-2146`) is population-balanced and contiguous, shows strong respect for political boundaries, and is reasonably compact. In this report, I compare the plan to two alternative plans called `GovPlan` and `CitizensPlan`. I find that these are also population-balanced and contiguous and have comparably strong respect for political boundaries but, crucially, each is markedly more compact than the House's proposed plan. In other words, I find that the Governor's Plan and the Citizens' Plan do a better job overall at accounting for the neutral criteria of redistricting.

In addition to the alternative plans outperforming the House Plan on neutral criteria, the maps differ significantly in their partisan fairness properties. `HB-2146` can be seen to systematically advantage the candidates of one major party over the other, when overlaid with a range of recent elections in Pennsylvania. In large part this is due to the "political geography" of Pennsylvania, in which the current patterns of concentration in electoral preferences create a landscape that is tilted towards Republicans. My analysis leads me to conclude that the Citizens' Plan, and especially the Governor's Plan, overcome this structural tilt to make fairer maps for the people of Pennsylvania—treating the parties even-handedly while still behaving responsively to shifts in voter preference—with no cost at all in the neutral criteria.

3 Introduction

The Commonwealth of Pennsylvania saw its population grow from 12,702,379 in the 2010 Decennial Census to 13,002,700 with the release of new numbers from 2020. Despite providing a boost from the 6th to the 5th largest state in the nation, the growth did not keep pace with the country as a whole, and Pennsylvania's congressional apportionment dropped from 18 districts to 17 for this cycle.

In the last ten-plus years, there has been a surge of citizen interest in redistricting around the nation, and many members of the public have tried their hands at drawing districts for the first time. One of those active citizens is Amanda Holt, who has been described in news reports as "a piano teacher from Upper Macungie" [7]. In its 2021-22 session, the Pennsylvania House of Representatives chose one of a collection of maps prepared by Holt and modified it to create the Congressional map that has now been passed as House Bill 2146.

In this report, I will be examining the design of Congressional districts in Pennsylvania. I will discuss the two enacted 18-district plans from the previous cycle (the legislative plan `2011-Enacted` from 2011 and the court's remedial plan `2018-Remedial` from 2018) alongside three proposed 17-district plans for the current cycle: the Governor's plan `GovPlan`, the public plan `CitizensPlan`, and the House's Holt-derived plan `HB-2146`.

I will use two main tools to study Pennsylvania Congressional redistricting. The first is a simple "overlay method" where districting plans are superimposed on actual recently observed voting patterns to record the plans' performance in a range of electoral conditions. The second is the "ensemble method" of generating large samples of legally valid redistricting plans that take the rules and criteria into account. I will use algorithmic ensembles to illustrate that partisan-blind redistricting in Pennsylvania does not tend to achieve partisan fairness. However, computational methods can also exhibit that there is a nearly inexhaustible supply of fairer maps that still obtain sterling scores on traditional criteria.

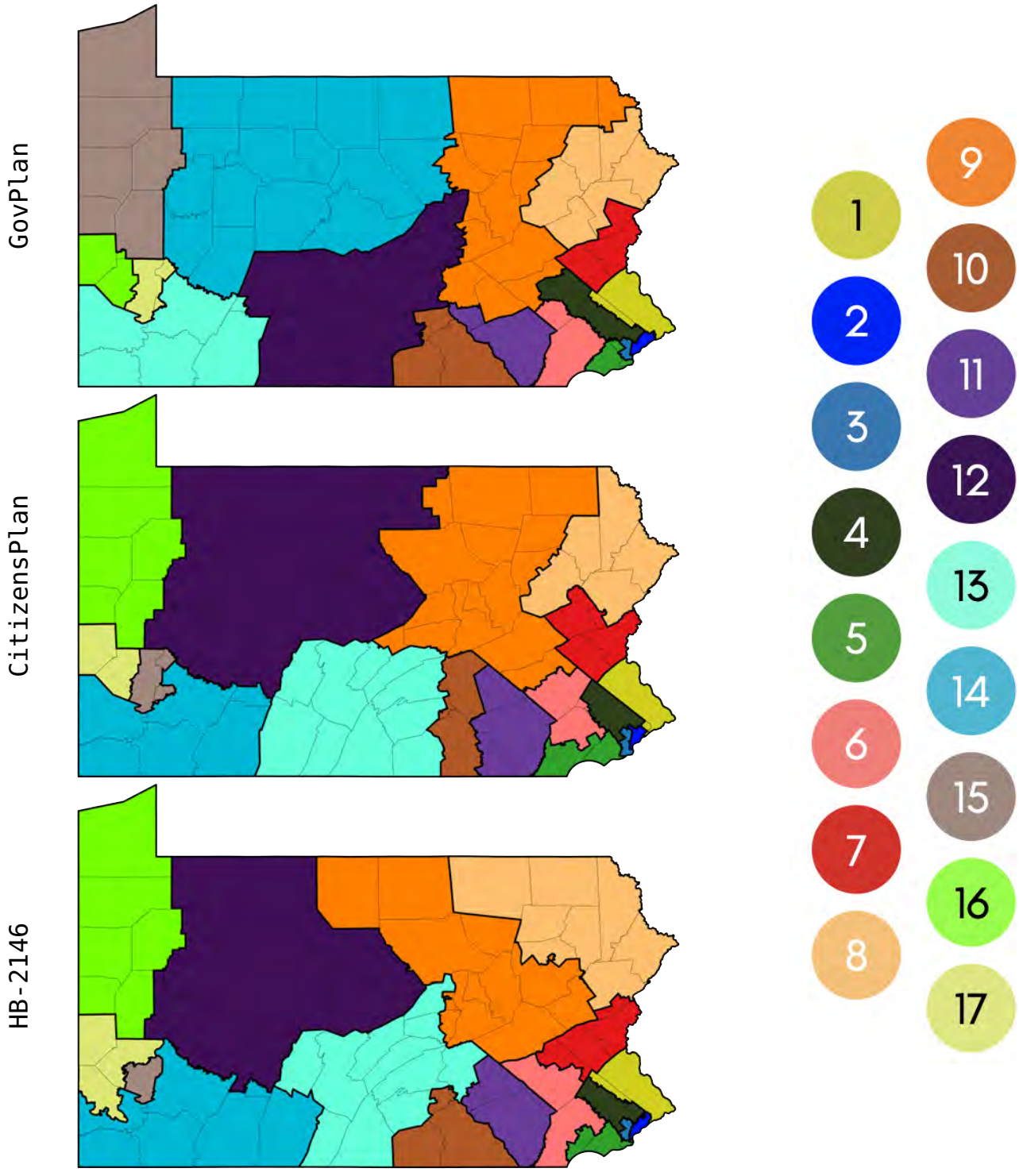


Figure 1: The three plans being compared in this report.

4 Review of redistricting criteria

Congressional redistricting for Pennsylvania is a matter of dividing up the 13,002,700 residents into 17 geographical subdivisions of the state. In doing so, we must balance a long and sometimes competing list of rules and priorities.

In 2018, the Pennsylvania Supreme Court struck down the congressional districts established in 2011 ("`2011-Enacted`") and ordered them to be replaced with a remedial plan drawn by a court-appointed expert ("`2018-Remedial`"). Justice Todd, writing for the majority in that decision, emphasized the roles of four major criteria for the design and adoption of a districting plan: population balance, compactness, contiguity, and respect for political boundaries. Quoting the opinion:

> Because these factors are deeply rooted in the organic law of our Commonwealth, and continue to be the foundational requirements which state legislative districts must meet under the Pennsylvania Constitution, we find these neutral benchmarks to be particularly suitable as a measure in assessing whether a congressional districting plan dilutes the potency of an individual's ability to select the congressional representative of his or her choice, and thereby violates the Free and Equal Elections Clause. [1]

These four considerations, as well as the federal requirement to safeguard electoral opportunity for minority groups, are echoed in the Redistricting Principles of the Governor's Advisory Council (henceforth, the "Principles"). Therefore these five criteria will be considered primary for this analysis.

4.1 Federal requirements

4.1.1 Population balance

Since the Reapportionment Revolution of the 1960s and 70s, courts have required serious attention to balancing the population across electoral districts in a plan, under a norm called *One Person, One Vote*. Over the decades, this has evolved to the tightest possible standard in practice: in most U.S. states, Congressional districts are fine-tuned so that their total population deviates by no more than one person from any district to any other.

Across the nation, the default dataset used to balance population is the Decennial Census release known as the PL94-171 data, named after the Public Law that mandated its publication. However, in Pennsylvania there is an alternative available: the Legislative Reapportionment Commission has released an adjusted block-level dataset known as LRC2, in which incarcerated people are geographically re-assigned to their communities of origin.[1] In the figures below, I will present the population balance of the plans with both the PL dataset and the LRC2 prison-adjusted alternative.

[1] The LRC also released LRC1, which corrects and updates some geographical definitions of precincts. The population figures reported here with respect to Census data were confirmed to be unchanged with the passage to the LRC1 dataset.

4.1.2 Minority opportunity to elect

Both the Voting Rights Act of 1965 and the U.S. Constitution protect against the denial, abridgement, or dilution of the vote for minority groups across the nation. For Congressional districting in Pennsylvania, this is of particular salience in Philadelphia, where people of color make up a majority of the voting age population and are collectively more numerous than the population of a district.[2]

In the previous cycle, the `2018-Remedial` map contained one majority-Black district (CD3 in Philadelphia) and a second majority-minority district. All three of the plans compared in this report retain the majority-Black character of CD3 and the majority-minority character of CD2. At the same time, the law clearly acknowledges that numerical majorities (50% plus one of voting age population) are neither necessary nor sufficient to provide effective opportunity to elect candidates of choice. Effectiveness of the comparison plans is discussed further in Section 6.

As a partial indicator of effective electoral opportunity, I considered recent at-large Philadelphia city council elections: the primary and general elections of 2015 and 2019. In 2015, Blondell Reynolds Brown and Derek S. Green were the candidates of choice for Black voters, according to an ecological inference analysis of voting polarization. In 2019, Green and Isaiah Thomas were the Black candidates of choice. Since all of these candidates ran city-wide, I can examine whether any district that intersects with Philadelphia had vote totals that supported these candidates.

4.2 Neutral criteria

4.2.1 Contiguity

Contiguity requires that, for each district, it is possible to transit from any part of the district to any other part, staying inside the district. That is, contiguity is the requirement that each district be composed of a single connected piece. In technical terms, for districts made from census blocks, the standard "rook-contiguity" definition holds that the connecting paths should pass through a sequence of census blocks that share boundary segments of positive length (and not through blocks that meet at corners).

4.2.2 Compactness

The two compactness metrics most commonly appearing in redistricting are the *Polsby-Popper score* and the *Reock score*. Polsby-Popper is a recent name for a metric from ancient mathematics: the isoperimetric ratio comparing a region's area to its perimeter via the formula $4\pi A/P^2$. Higher scores are considered more compact, with circles uniquely achieving the optimum score of 1. Reock is a different measurement of how much a shape differs from a circle: it is computed as the ratio of a region's area to that of its circumcircle, defined as the smallest circle in which the region can be circumscribed. From this definition, it is clear that it too is optimized at a value of 1, which is achieved only by circles. In addition, the 2018 Court Order specified three more metrics—*Schwartzberg*, *Convex Hull*, and *Population Polygon*—that should be reported for every plan.[3]

[2] Philadelphia White non-Hispanic VAP: 37.8%, Black VAP: 39.8%, Hispanic VAP: 13.1%, Asian VAP: 9.4%. Lehigh and Monroe counties have people of color making up 30-40% of voting age population, while the range is 20-30% in many other counties (namely, Allegheny, Berks, Chester, Forest, Montgomery, and Northampton).

[3] Schwartzberg is $P/2\sqrt{\pi A}$. Convex Hull is the ratio of the district's area to that of its convex hull, or "rubber-band enclosure." And Population Polygon is the ratio of the district's population to the state's population within the convex hull. All parties submitting maps to the Court were required to report these five scores for each district in the plan, but the Court did not specify how these numbers would be compared across plans.

All five of these scores depend on the contours of a district and have been criticized as being too dependent on map projections or on cartographic resolution [4, 5]. Recently, mathematicians have argued for using discrete compactness scores, taking into account the units of Census geography from which the district is built. The most commonly cited discrete score for districts is the *cut edges score*, which counts how many adjacent pairs of geographical units receive different district assignments. In other words, cut edges measures the "scissors complexity" of the districting plan: how much work would have to be done to separate the districts from each other? Plans with a very intricate boundary would require many separations. This score improves on the contour-based scores by better controlling for factors like coastline and other natural boundaries, and by focusing on the units actually available to redistricters rather than treating districts like free-form Rorschach blots.

4.2.3 Respect for political boundaries

One of the most common redistricting principles active in laws and guidelines for redistricting is the respect for political subdivisions: counties, cities, and other relevant political and administrative geographies should be kept intact in districts as much as practicable.

In Pennsylvania, there are 67 counties, further subdivided into 2572 municipalities.[4]

4.3 Other traditional principles

The LWV opinion from 2018 continues by identifying three more that can reasonably be considered once the fundamental principles are in place.

> We recognize that other factors have historically played a role in the drawing of legislative districts, such as the preservation of **prior district lines**, protection of **incumbents**, or the maintenance of the **political balance** which existed after the prior reapportionment. See, e.g., Holt I, 38 A.3d at 1235. However, we view these factors to be wholly subordinate to the neutral criteria of compactness, contiguity, minimization of the division of political subdivisions, and maintenance of population equality among congressional districts. These neutral criteria provide a “floor” of protection for an individual against the dilution of his or her vote in the creation of such districts. [1, emph. added]

The Principles of the Governor’s council spell out a version of political balance in their reference to "partisan fairness and proportionality" as well as "responsiveness and competitiveness." They also cite the traditional principle of respect for **communities of interest**. I will defer the political balance considerations to Section 7 but will briefly outline the other criteria here.

[4] The Census Bureau publishes these in its COUSUB file; Pennyslvania is one of the states in which county subdivisions are equivalent to minor civil divisions in the Census nomenclature. These are further classified as cities, towns, townships, and boroughs. As a technical note, 12 of the COUSUBs are split across counties, so 2572 is the number after dividing them to nest inside counties.

4.3.1 Least change

In 2018, the Pennsylvania Supreme Court ordered that the Congressional districts enacted in 2011 be replaced with a map that was deemed to better uphold traditional principles as well as the Free and Equal Elections Clause in the state constitution. This 18-district remedial plan, drawn by a court-appointed expert, has now been in place for two Congressional elections, those of 2018 and 2020. As the Court's opinion makes clear, it would be reasonable to prefer a plan that is least disruptive to the `2018-Remedial` plan. The identification of a least-change plan is made somewhat challenging in Pennsylvania by the loss of a district; still, it is possible, for each district in a new plan, to see which `2018-Remedial` district contains the largest share of its population and add up the number of people who are *not* assigned to that target district. For example, all three plans under discussion (`GovPlan`, `CitizensPlan`, and `HB-2146`) have in common that CD 3 in the new plan has its largest overlap with the one labeled CD 3 in the previous plan; that district is currently represented by Dwight Evans. That means the displacement score for the new plans will count the number of people who are now assigned to District 3 but were not previously represented by Dwight Evans. It is reasonable to prefer plans with lower displacement from the remedial plan, given that it was put in place by the Court as a model of fair districting.

4.3.2 Incumbency

Relatedly, we can compare the plans' consideration of incumbency by considering whether new districts are drawn so as to force current incumbents to compete—this usually goes by the name of "double-bunking." Some states encourage line-drawers to minimize double-bunking, while other states require that incumbent addresses not be considered. I will report double-bunking statistics below, but make no assumption that less double-bunking is necessarily better.

4.3.3 Communities of interest

Finally, a conceptually important traditional principle that has often been hard to measure is respect for *communities of interest*, or "COIs." In past census cycles, though line-drawing bodies have often solicited public comment at hearings and in writing, the redistricting community has generally lacked a systematic mechanism for connecting public testimony to mapping format. In this cycle, free web tools have emerged that have made it possible for community input to be visible in the line-drawing process. COIs are discussed further in Section 6.

5 Comparison of metrics for proposed Congressional plans

In this section, I review some quantitative comparisons to establish the conformance of the plans under consideration to the neutral criteria identified as being of primary importance. First, all three plans attain *de minimis* population deviation with respect to the official Census data.[5]

With respect to the prisoner-adjusted allocations found in LRC2, the plans have slightly higher levels of observed deviation, with the Governor's plan slightly tighter than the other two.

Table 1: Comparison of the population deviation across plans.

Population deviation – Census

	max positive deviation	max negative deviation	top-to-bottom deviation
GovPlan	–	−1	1
CitizensPlan	–	−1	1
HB-2146	–	−1	1

Population deviation – Prisoner-adjusted

	max positive deviation	max negative deviation	top-to-bottom deviation
GovPlan	3686	−4863	8549
CitizensPlan	3875	−5021	8896
HB-2146	3933	−4932	8865

Next, I enumerate the number of counties that are split across multiple districts in the respective plans. When a county is split, I record its number of pieces (the number of districts that it touches). All three plans have strong respect for political boundaries, splitting 14-16 of the state's 67 counties and only 16-18 of over 2500 municipalities.

Table 2: Comparing the plans' conformance to political boundaries.

Political boundaries

	county splits (out of 67)	county pieces	muni splits (out of 2572)	muni pieces
GovPlan	16	35	18	37
CitizensPlan	14	30	16	33
HB-2146	15	33	16	34

[5] The same one-person deviation is maintained if the dataset shifts to the adjusted LRC1 data referenced above.

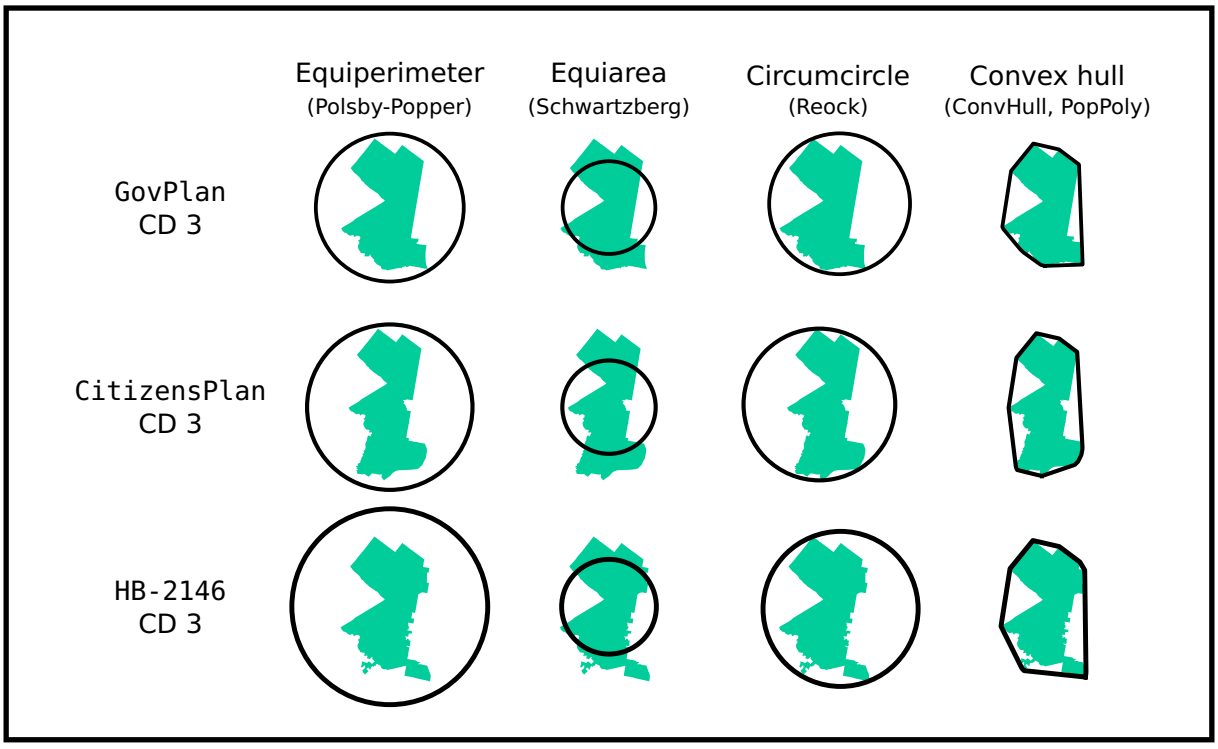
Another fundamental redistricting principle is compactness, which can be measured by a huge variety of metrics. Here, I provide six different ways of scoring a plan, defined in the previous section. The Governor's Plan rates most compact in five of these six metrics, with the Citizens' Plan slightly more compact on Reock. HB-2146 is the least compact across the board, often by a significant margin.

Table 3: Comparing compactness scores via one discrete and five contour-based metrics. Each contour-based metric works by comparing the shape to an associated contour. The comparison is illustrated on CD 3 from each of the plans under discussion.

Compactness

	block cut edges (lower is better)	average Polsby-Popper (higher is better)	average Reock (higher is better)
GovPlan	5185	0.381	0.431
CitizensPlan	5266	0.376	0.451
HB-2146	5907	0.321	0.409

	average Schwartzberg (higher is better)	average convex hull (higher is better)	average pop. polygon (higher is better)
GovPlan	1.653	0.826	0.783
CitizensPlan	1.669	0.812	0.772
HB-2146	1.820	0.799	0.752



Using the least-change metric described in the last section, we can see that GovPlan keeps the districts intact to the greatest extent of these three alternatives.

Table 4: In this table, maps are compared by finding a matching (i.e., a correspondence) from the new districts to their best fit in the previous map. The displacement score is then computed by adding up the people who don't share that previous district assignment. Under this metric, the Governor's Plan most closely resembles the court's remedial map.

Least change

	relabeling	displacement
GovPlan	(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18)	2,438,850
CitizensPlan	(1, 2, 3, 4, 5, 6, 7, 8, 12, 10, 11, 15, 13, 14, 18, 16, 17)	2,755,864
HB-2146	(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 15, 13, 14, 18, 16, 17)	2,797,612

Finally, I describe the division of incumbent addresses among the districts in the three plans under discussion, using the most accurate addresses I have been able to obtain. Given that an 18-district plan is contracting to just 17 districts, it is inevitable that some incumbents be paired. Each of the three plans under discussion has the same level of incumbent pairing.

Table 5: Each of the three plans has two districts that pair incumbents and one district with no incumbent.

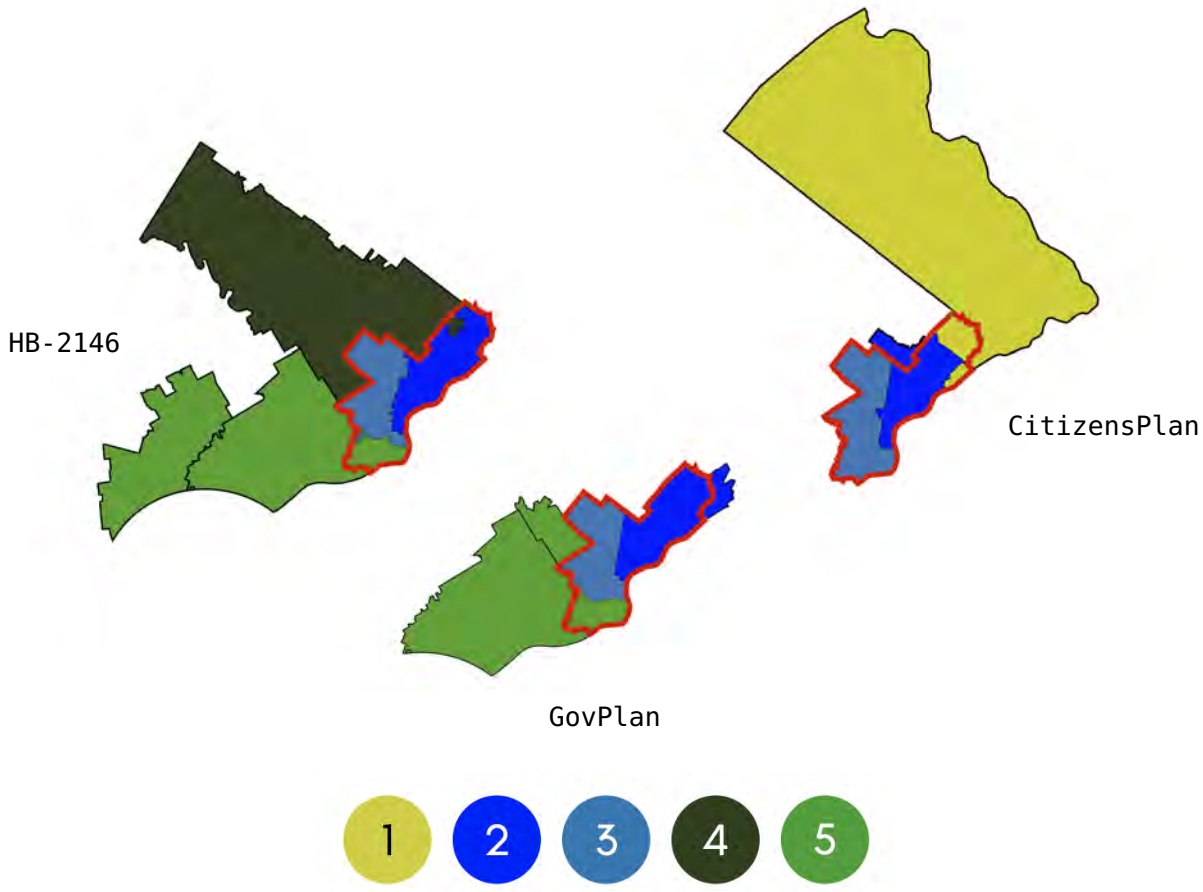
Incumbents by district

CD	GovPlan	CitizensPlan	HB-2146
1	Fitzpatrick	Fitzpatrick, Boyle	Fitzpatrick
2	Boyle	—	Boyle
3	Evans	Evans	Evans
4	—	Dean	Dean
5	Dean,Scanlon	Scanlon	Scanlon
6	Houlahan	Houlahan	Houlahan
7	Wild	Wild	Wild
8	Cartwright	Cartwright	Meuser, Cartwright
9	Meuser	Meuser, Keller	Keller
10	Perry	Perry	Perry
11	Smucker	Smucker	Smucker
12	Joyce, Keller	Thompson	Thompson
13	Reschenthaler	Joyce	Joyce
14	Thompson	Reschenthaler	Reschenthaler
15	Kelly	Doyle	Lamb, Doyle
16	Lamb	Kelly	Kelly
17	Doyle	Lamb	—

6 Communities of interest and minority opportunity to elect

Both GovPlan and CitizensPlan were drawn after a robust public input process and in view of hundreds of collected comments and suggestions. By contrast, my understanding is that the Holt map was based on a metric-centered process that began with a single person working in isolation. To illustrate some of the differences that these origin stories suggest, I will focus on Philadelphia, which was both the location of the densest public commentary (see Figure 3) and is the city most salient for VRA consideration—for Black voters in particular, who are the plurality racial group—in the context of Congressional redistricting.

Figure 2: Comparing the districts that touch Philadelphia (red outline) in the three plans. Other county lines are also shown.



Philadelphia has enough total population for roughly 2.1 Congressional districts, and its residents share a set of broad interests in addition to exhibiting great diversity. This suggests that the city should contain all or most of two districts and a small portion of a third, if the criteria of political boundaries and COIs are paramount. In the plans under consideration, GovPlan has three districts (CD 2, 3, 5) touching Philadelphia, and CitizensPlan has three (CD 1, 2, and 3). The House's Holt-derived plan HB-2146 has four districts that touch the city (CD 2, 3, 4, 5)—with district 4 taking a trident-shaped scoop out of North Philadelphia and district 5 weaving across city lines in two different places in the Southwest.

One way to measure whether the Philadelphia districts effectively secure electoral opportu-

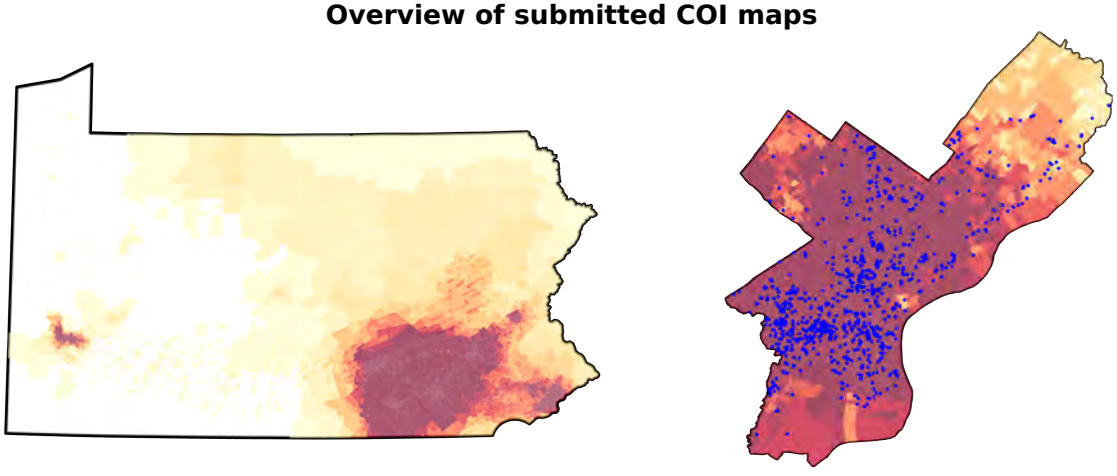
nity is to examine the vote totals from the at-large City Council elections of 2015 (where Black candidates of choice were B.Brown and D.Green) and 2019 (where Black candidates of choice were D.Green and I.Thomas). In these elections, voters could select up to five candidates, and five were ultimately elected.

With respect to the 2015 elections, GovPlan has D.Green as a top-two finisher in all three of its Philadelphia districts, with B.Brown essentially tied in CD 3. CitizensPlan has very strong outcomes for both Brown and Green in its CD 3, but districts 1 and 2 do not have either one in the top two finishers. In HB-2146 as well, only CD 3 has Brown and Green as the top two, while White-preferred candidates do better in districts 2 and 4, and district 5 has a mixed outcome.

In the 2019 outcomes, the GovPlan districts in Philadelphia all have strong showings for Green and Thomas as well as for city-wide progressive favorite Helen Gym. This is true in two out of three CitizensPlan districts that touch the city, while the story is more mixed in HB-2146, where in particular district 4 is way out of line with the city as a whole.

A possible explanation for these indications of more effective opportunity districts in GovPlan is a robust process for collecting public input in the lead-up to line-drawing. The Governor's office set up a website (portal.pennsylvania-mapping.org) to accept comments and maps from the public. One option for submitters was to include a map paired with narrative comments describing their communities of interest. Active from September to December of 2021, the portal received 126 COI submissions. In addition, grassroots organizations like Pennsylvania Voice (pennsylvaniavoice.org) collected hundreds of additional submissions through the same online mapping platform, called Districtr.

Figure 3: This heatmap shows 962 areas mapped by public commenters through the Districtr tool to show their communities of interest. Redder areas received more coverage, with the darkest areas in the heatmap indicating that ≥ 20 submitters described overlapping neighborhood and community areas in that location. The Philadelphia inset also shows (with blue dots) the locations of hundreds of landmarks, or points of interest, placed by those commenters as locations that anchor their communities.



By drawing lines in view of public testimony and the local definitions of community, GovPlan is able to create three Philadelphia-heavy districts (two that are over 90% city districts and a third with over 100,000 Philadelphians) where voting behavior comports with the city overall, better amplifying the voices of city residents. The fact that these districts are better aligned with local preferences of Black voters than in HB-2146, despite having similar shares of Black voting age population, shows that electoral opportunity is a matter of aligning community and not just targeting demographic metrics.

7 Partisan fairness

7.1 Theories of partisan fairness

There are numerous notions of partisan fairness that can be found in the scholarly literature and in redistricting practitioner guides and software. Many of them are numerical, in the sense that they address *how a certain quantitative share of the vote should be translated to a quantitative share of the seats* in a state legislature or Congressional delegation. Others are symmetry-based and deal with ideas of role-reversal between the parties.

The numerical notions and the symmetry notions of partisan fairness all tend to agree on one central point: an electoral climate with a roughly 50-50 split in partisan preference should produce a roughly 50-50 representational split. I will call this the *Close-Votes-Close-Seats* principle. Recent Pennsylvania statewide elections often have voting that is close to even between the two major parties, but the HB-2146 plan approved by the House of Representatives can be seen to systematically convert even voting patterns to a significant Republican advantage in the Congressional delegation.

Importantly, Close-Votes-Close-Seats is not tantamount to a requirement for proportionality. Rather, it is closely related to the principle of *Majority Rule*: a party or group with more than half of the votes should be able to secure more than half of the seats. In fact, Close-Votes-Close-Seats is essentially a corollary (or byproduct) of Majority Rule, making it a centrally important small-d democratic principle. It is not practicable to design a map that *always* attains these properties, but by contrast a map that *consistently thwarts* them should be closely scrutinized and usually rejected.

Unlike proportionality, neither Close-Votes-Close-Seats nor Majority Rule has any bearing on the preferred representational outcome when one party has a significant voting advantage: these principles are silent about whether 70% vote share should secure 70% of the seats, as proportionality would dictate, or 90% of the seats, as supporters of the efficiency gap would prefer. The size of the "winner's bonus" is not at all prescribed by a Close-Votes-Close-Seats norm.

7.2 The limitations of political geography

Some scholars have argued that all numerical ideals, including Close-Votes-Close-Seats, ignore the crucial *political geography*—this school of thought reminds us that the location of votes for each party, and not just the aggregate preferences, has a major impact on redistricting outcomes. In [6], my co-authors and I gave a vivid demonstration of the impacts of political geography in Massachusetts: we showed that for a ten-year span of observed voting patterns, even though Republicans tended to get over one-third of the statewide vote, it was impossible to draw a single Congressional district with a Republican majority. That is, the geography of Massachusetts Republicans locked them out of Congressional representation. It is therefore not reasonable to charge the Massachusetts legislature with gerrymandering for having produced maps which yielded all-Democratic delegations; they could not have done otherwise.

In Pennsylvania, this is not the case. The alternative plans demonstrate that it is possible to produce maps that give the two major parties a roughly equal opportunity to elect their candidates. These plans are just examples among many thousands of plausible maps that convert voter preferences to far more even representation by party. In Congressional redistricting, present-day Pennsylvania geography is easily conducive to a seat share squarely in line with the vote share.

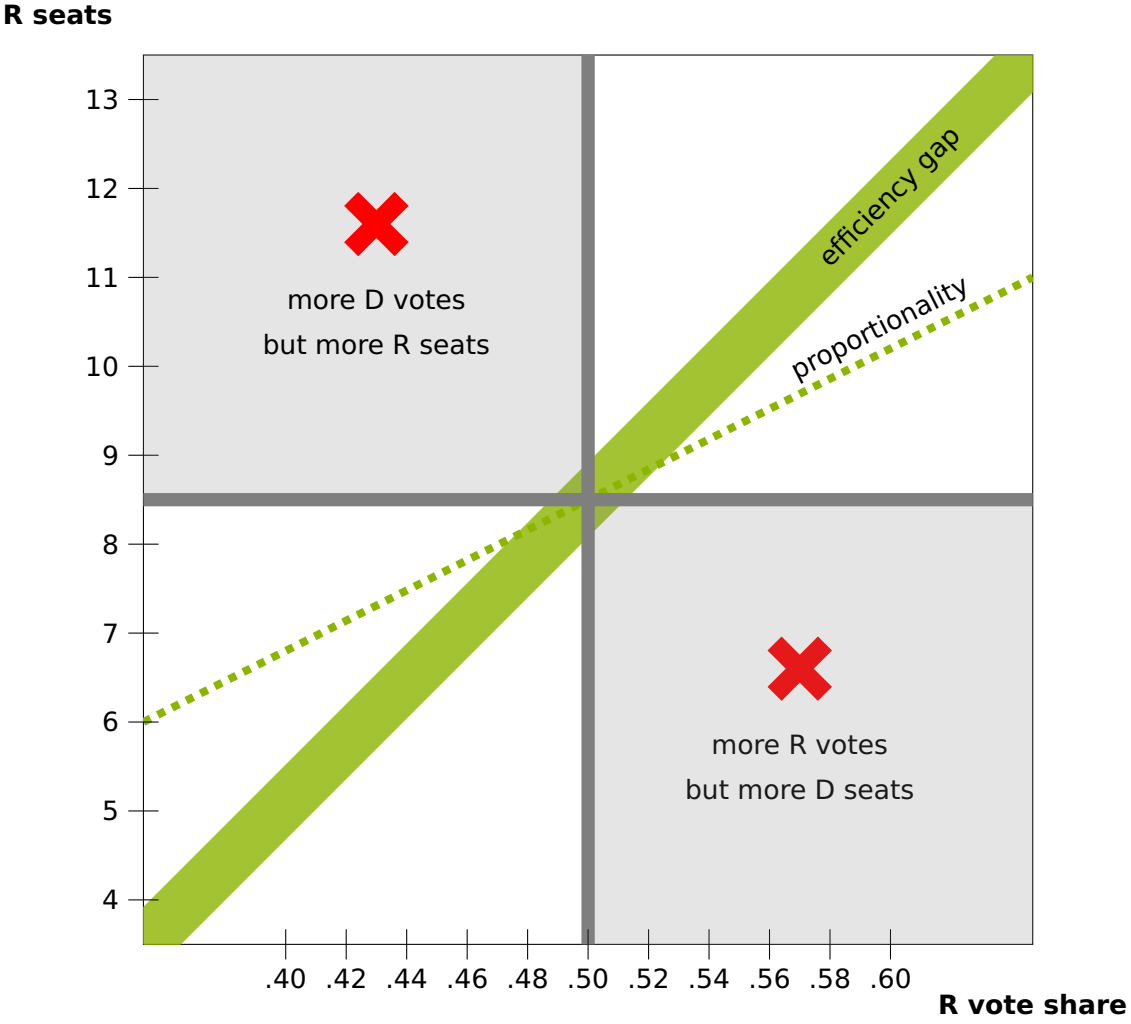
The clear conclusion is that the political geography of Pennsylvania today does not obstruct the selection of a map that treats Democratic and Republican voters fairly and even-handedly.

8 Votes versus seats

To illustrate Close-Votes-Close-Seats, Majority Rule, and other norms of partisan fairness, it is helpful to examine a plot that shows vote shares on one axis and seat outcomes on the other. A plan can be overlaid with a vote pattern to see how the seat share relates to the vote share for that election. Repeating this across a range of different kinds of elections provides a robust view of the performance of the plan.

Majority Rule, then, translates to the idea that the Southeast and Northwest quadrants should be avoided. Close-Votes-Close-Seats now says that if an election is near even placing it horizontally near the center of the plot, then the vertical position should be aimed at the bulls-eye in the middle of the plot rather than falling consistently above or below the target. And many other ideals of fairness, like proportionality and the efficiency gap, can be realized as lines or zones in the plot. This is summarized in Figure 4.

Figure 4: A seats-versus-votes plot. Below, we will plot the results from overlaying a districting plan on a series of elections. The x-coordinate is the vote share for Republicans in that election. The y-coordinate is the number of Republican seats. The figure is set up to show the 50-50 mark as a "bulls-eye" target in the center, meaning that a close vote produced even representation.



8.1 Overlaying the plans on recent elections

To see how a map performs, we can overlay the elections in our dataset and observe how the points fill out the seats-votes plot.

Figure 5: In this figure, the top row shows the outcomes when `2011-Enacted` and `2018-Remedial` are serially overlaid on recent Pennsylvania elections. We see that the overturned plan consistently converts close voting to a Republican representational advantage, while the court's remedial plan maintains electoral responsiveness while upholding Close-Votes-Close-Seats.

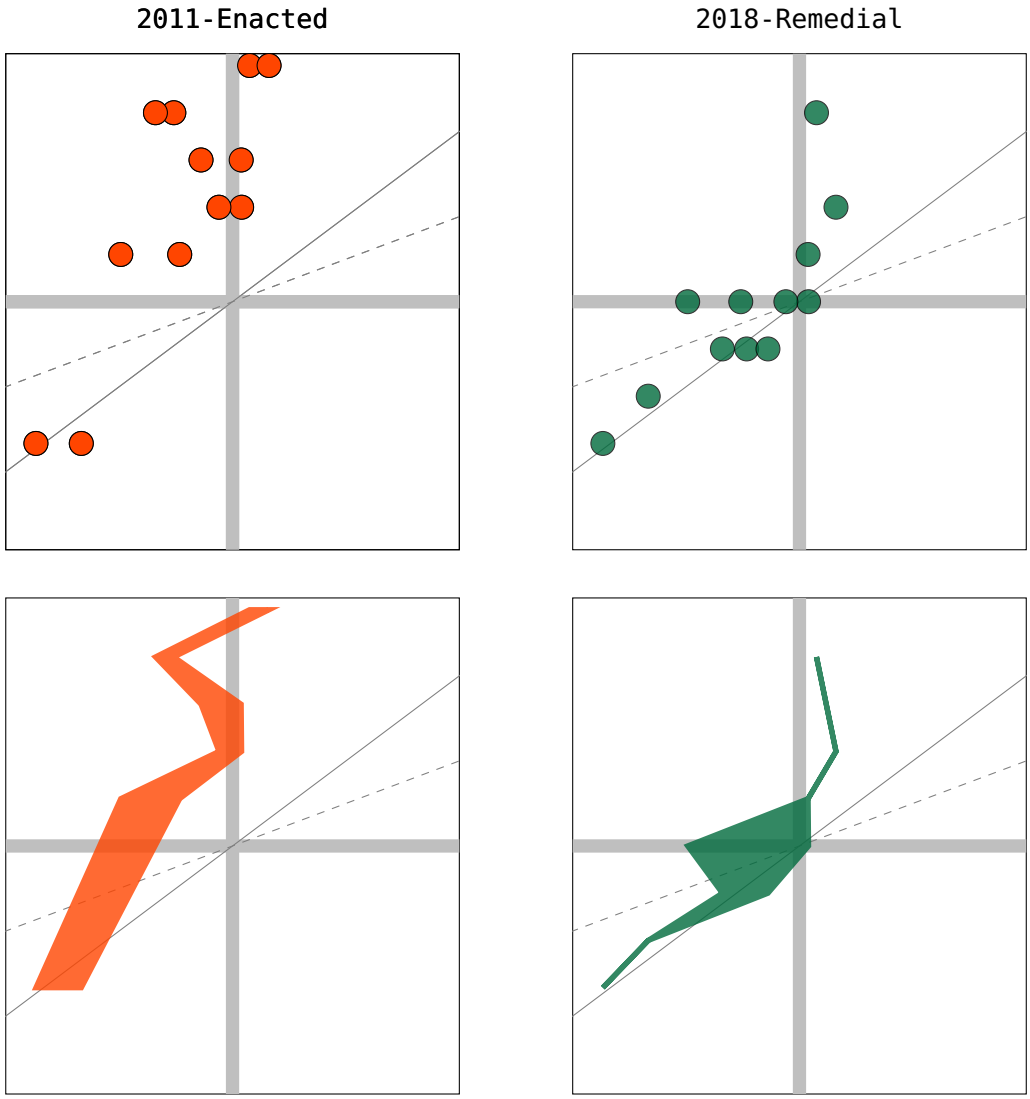
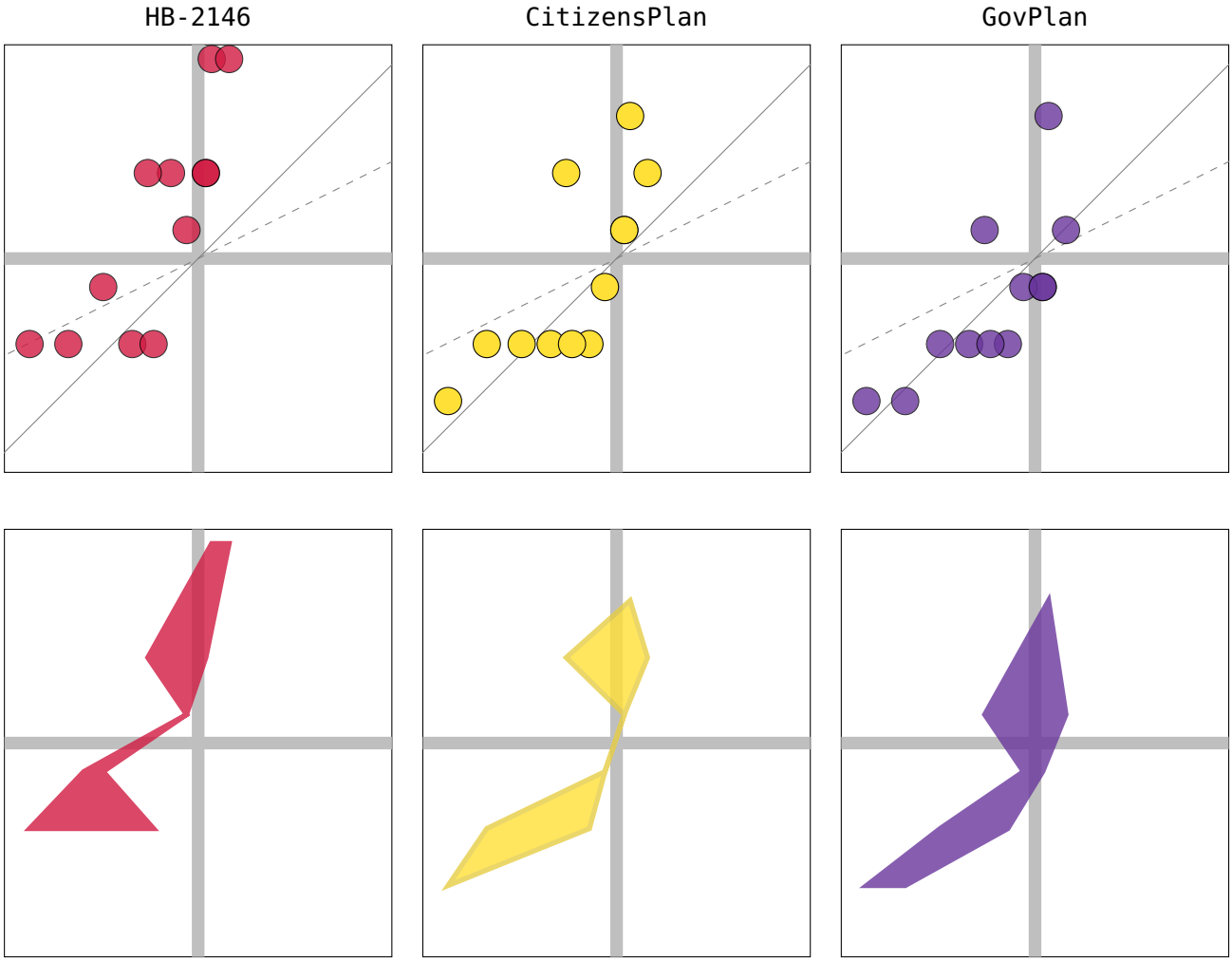


Figure 6: This time, the three new proposed plans are overlaid on the same elections. HB-2146 entrenches a Republican advantage, while CitizensPlan and especially GovPlan are far superior at leveling the partisan playing field.



Just as in 2018, there is no need to accept a plan that provides for a marked partisan tilt; options are available to the court that maintain excellent adherence to the traditional districting principles while treating the parties equally and even-handedly in terms of electoral opportunity. The 2018 remedial plan corrected the bias in its predecessor, and that same pattern is visible in the maps being compared today.

8.2 Partisan fairness metrics

In this section, I present a series of images that reinforce the theme elaborated above: the political geography of Pennsylvania creates a districting landscape that is tilted toward Republican advantage. Thus, blindly drawn Pennsylvania Congressional plans are not conducive to partisan fairness under any partisan metric that I have examined.

However, it is possible to level out this tilted playing field and produce a plan that is far more fair while still upholding the traditional principles. This is illustrated by both `GovPlan` and `CitizensPlan`, in contrast to `HB-2146`.

The metrics seen here can be briefly defined as follows. Without endorsing any of these as normatively correct, we will see that they all report consistent findings about the performance of the three plans considered here.

- *Efficiency gap* is based on the idea of wasted votes, defined as any winning votes in excess of 50%, or any losing votes at all. The EG score is computed by taking total Republican wasted votes minus total Democratic wasted votes, divided by total votes. If the EG score has a magnitude of greater than 8 percentage points, that flags a presumptive gerrymander [8].
- Eguia's artificial partisan advantage [9] compares the outcomes under districted plurality elections to the outcomes under ostensibly neutral political subdivisions, such as counties. It is calculated here by taking counties as the fundamental territorial subdivision of the state: the baseline for political performance for Democrats is the share of the population that lives in counties won by Democrats in a particular election. If the Democratic seat share outperforms that baseline, the metric is positive; otherwise, it is negative.
- The mean-median score is calculated by taking the mean Republican vote share in a district minus the median [10]. It is described as indicating how much of the vote in a state is needed to capture half of the representation.
- The partisan bias score calculates how much of the representation would be captured by each party if the election underwent a uniform partisan swing to a 50-50 share [10]. This is meant to approximate the counterfactual of exactly even voting, and is measured against the presumption that even voting should secure even representation.

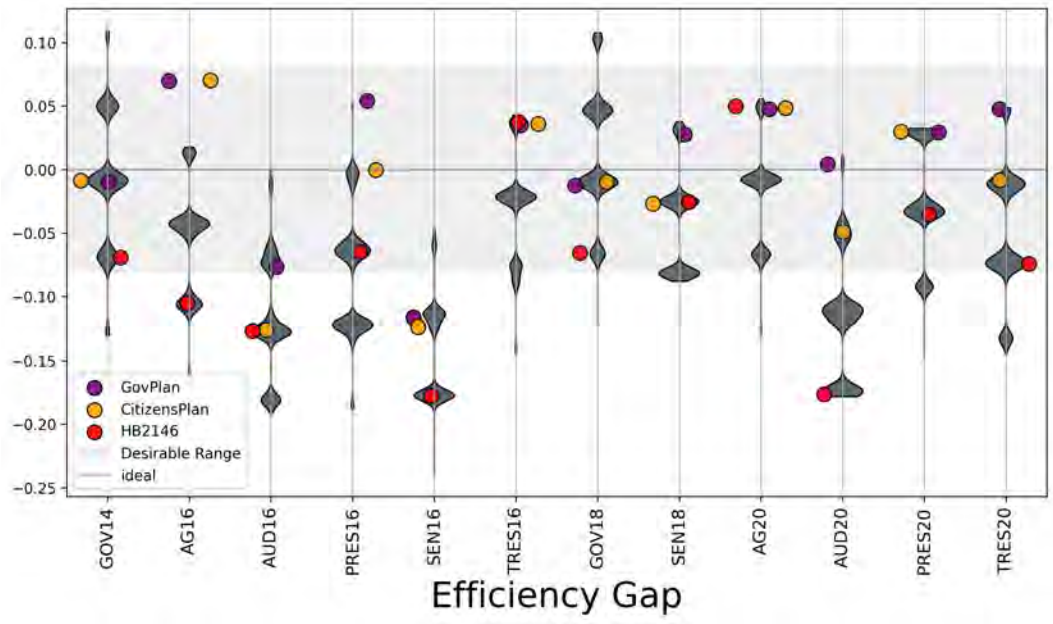
Each of the four metrics presented here is signed, and in each of the three plots, the positive direction indicates Democratic advantage and the negative direction indicates Republican advantage. Therefore it can be useful to sum the metrics over all twelve elections in this dataset; this way, it is easy to distinguish overall whether the advantage always tends to favor the same party.

Table 6: Summary of partisan metrics, summed over the twelve elections in the dataset. In each case, zero is ideal, positive scores indicate overall Democratic advantage, and negative scores indicate overall Republican advantage.

	total efficiency gap	total Eguia metric	total mean-median	total partisan bias
`GovPlan`	+0.10	−0.05	−0.01	−0.18
`CitizensPlan`	−0.17	−0.34	−0.10	−0.65
`HB-2146`	−0.83	−0.99	−0.29	−1.23

The playing field itself is illustrated by the violin plots in Figures 7-8, which show in gray the values achieved by the plans in the ensemble. The colored dots show the plan performance for each of the three proposed plans against the voting pattern in the indicated elections.

Figure 7: Here, an ensemble of 100,000 randomly drawn districting plans (shown in gray) is scored on the *efficiency gap* metric and on Eguia's county-based metric of *artificial partisan advantage*. Random plans tend to exhibit pronounced advantage to Republicans across this full suite of recent elections. `GovPlan` and `CitizensPlan` are seen to correct this tendency.



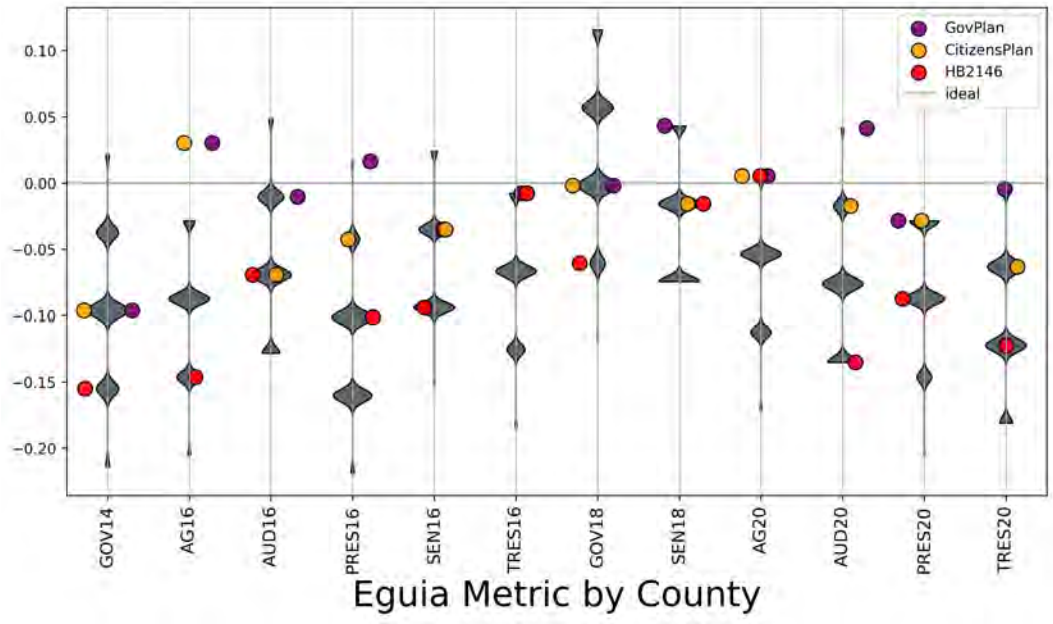
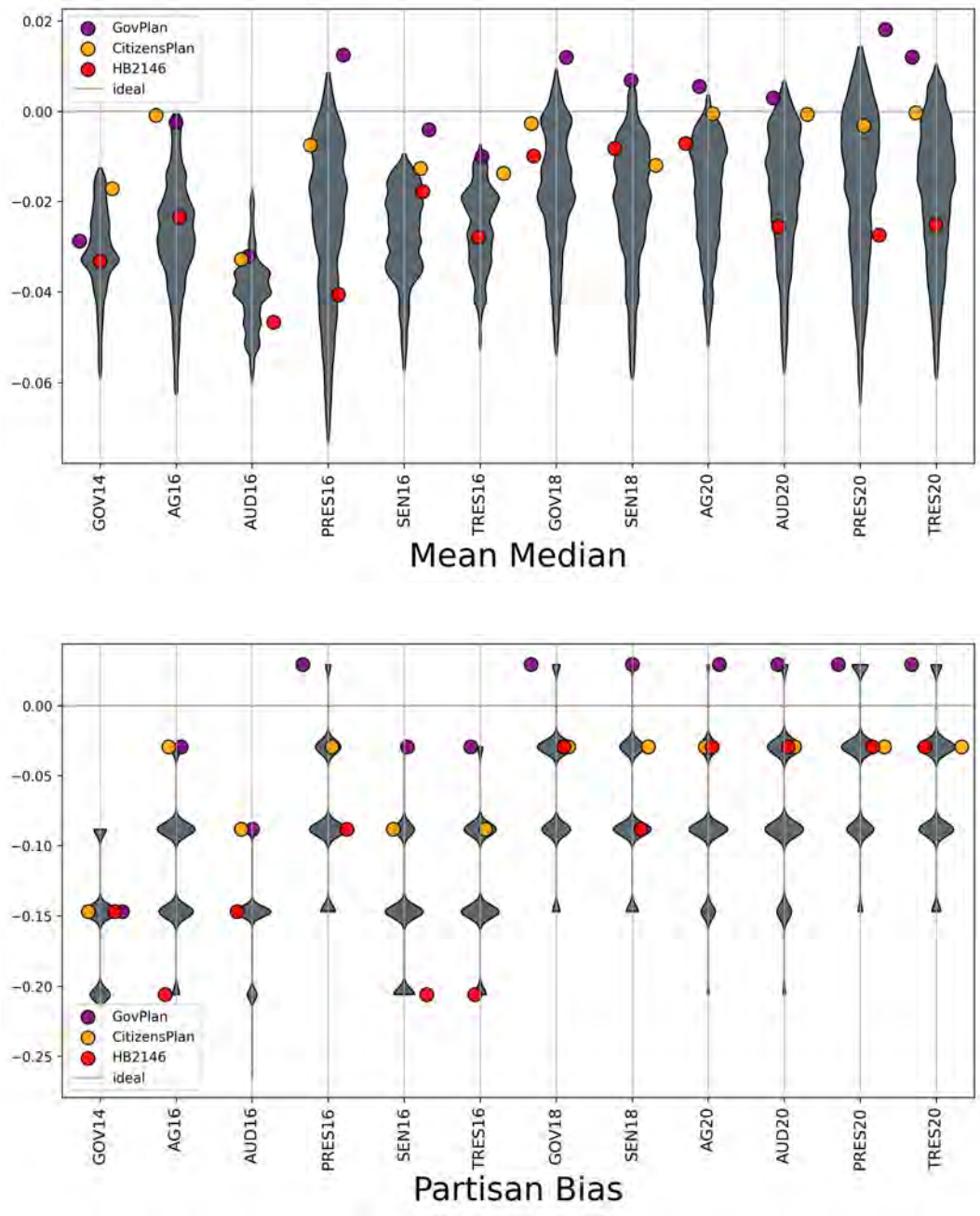


Figure 8: This time, the metrics are from the *partisan symmetry* family, namely the *mean-median score* and the *partisan bias* score. Once again, random plans favor Republicans, while `GovPlan` and `CitizensPlan` temper that tendency.



9 Conclusion

To summarize my findings, I will first return to the majority opinion of the Pennsylvania Supreme Court from 2018 as a touchstone. Justice Todd, having described the potential of computational redistricting to gerrymander, then strikes a more optimistic note.

> We are confident, however, that, technology can also be employed to aid in the expeditious development of districting maps, the boundaries of which are drawn to scrupulously adhere to neutral criteria. Indeed, as this Court highlighted in Holt I, "the development of computer technology appears to have substantially allayed the initial, extraordinary difficulties in" meeting such criteria. Holt I, 38 A.3d at 760; see also id. At 750 (noting that, since 1991, technology has provided tools allowing mapmakers to "achieve increasingly 'ideal' districts") (citing Gormley, Legislative Reapportionment, at 26–27, 45–47); see also Larios v. Cox, 305 F.Supp.2d. 1335, 1342 (N.D. Ga. 2004) ("given recent advances in computer technology, constitutional plans can be crafted in as short a period as one day"). As this Court views the record in this case, in the context of the computer technology of 2018, this thesis has clearly been proven.

These words ring true in 2022. Indeed, the science of computational redistricting has made great strides even in the last four years, and it is now possible to use algorithmic assistance not only to understand the universe of possibility created by the rules and priorities of redistricting, but to find novel combinations and configurations of geography that would have been very difficult to discover in previous census cycles. However, we do not need to outsource our line-drawing to the machines. Plans made with careful consideration of public input, like the Citizens' Plan and the Governor's Plan, can make good on the promise of computational redistricting while centering human geography and shared community interests. These plans reflect the voices of people across the state, secure excellent foundational scores on traditional criteria, and neutralize the tendency for blindly drawn plans to exhibit significant partisan bias. Thus, while protecting all of the good-government principles at play, we can secure a map that treats the parties even-handedly and safeguards the accountability of the representatives to the voters.

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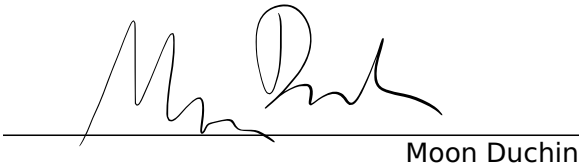
I declare under penalty of perjury that the foregoing is true and correct.

Executed this 24th day of January, 2021.



Moon Duchin

Moon Duchin CV

Moon Duchin

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Mathematics · STS · Tisch College of Civic Life | Tufts University

Education

University of Chicago MS 1999, PhD 2005
Mathematics
Advisor: Alex Eskin Dissertation: *Geodesics track random walks in Teichmüller space*

Harvard University BA 1998
Mathematics and Women's Studies

Appointments

Tufts University
Professor of Mathematics 2021—
Assistant Professor, Associate Professor 2011–2021

Director | Program in Science, Technology, & Society 2015–2021
(on leave 2018–2019)

Principal Investigator | MGGG Redistricting Lab 2017—

Senior Fellow | Tisch College of Civic Life 2017—

University of Michigan
Assistant Professor (postdoctoral) 2008–2011

University of California, Davis
NSF VIGRE Postdoctoral Fellow 2005–2008

Research Interests

Data science for civil rights, computation and governance, elections, geometry and redistricting.
Science, technology, and society, science policy, technology and law.
Random walks and Markov chains, random groups, random constructions in geometry.
Large-scale geometry, metric geometry, isoperimetric inequalities.
Geometric group theory, growth of groups, nilpotent groups, dynamics of group actions.
Geometric topology, hyperbolicity, Teichmüller theory.

Awards & Distinctions

Research Professor - MSRI Program in Analysis and Geometry of Random Spaces Spring 2022
Guggenheim Fellow 2018
Radcliffe Fellow - Evelyn Green Davis Fellowship 2018–2019
Fellow of the American Mathematical Society elected 2017
NSF C-ACCEL (PI) - Harnessing the Data Revolution: Network science of Census data 2019–2020
NSF grants (PI) - CAREER grant and three standard Topology grants 2009–2022
Professor of the Year, Tufts Math Society 2012–2013
AAUW Dissertation Fellowship 2004–2005
NSF Graduate Fellowship 1998–2002
Lawrence and Josephine Graves Prize for Excellence in Teaching (U Chicago) 2002
Robert Fletcher Rogers Prize (Harvard Mathematics) 1995–1996

Mathematics Publications & Preprints

The (homological) persistence of gerrymandering
Foundations of Data Science, online first. (with Thomas Needham and Thomas Weighill)

You can hear the shape of a billiard table: Symbolic dynamics and rigidity for flat surfaces
Commentarii Mathematici Helvetici, to appear. arXiv:1804.05690
(with Viveka Erlandsson, Christopher Leininger, and Chandrika Sadanand)

Conjugation curvature for Cayley graphs
Journal of Topology and Analysis, online first. (with Assaf Bar-Natan and Robert Kropholler)

A reversible recombination chain for graph partitions
Preprint. (with Sarah Cannon, Dana Randall, and Parker Rule)

Recombination: A family of Markov chains for redistricting
Harvard Data Science Review. Issue 3.1, Winter 2021. online. (with Daryl DeFord and Justin Solomon)

Census TopDown: The impact of differential privacy on redistricting
2nd Symposium on Foundations of Responsible Computing (FORC 2021), 5:1–5:22. online.
(with Aloni Cohen, JN Matthews, and Bhushan Suwal)

Stars at infinity in Teichmüller space
Geometriae Dedicata, Volume 213, 531–545 (2021). (with Nate Fisher) arXiv:2004.04321

Random walks and redistricting: New applications of Markov chain Monte Carlo
(with Daryl DeFord) For edited volume, Political Geometry. Under contract with Birkhäuser.

Mathematics of nested districts: The case of Alaska
Statistics and Public Policy. Vol 7, No 1 (2020), 39–51. (w/ Sophia Caldera, Daryl DeFord, Sam Gutekunst, & Cara Nix)

A computational approach to measuring vote elasticity and competitiveness
Statistics and Public Policy. Vol 7, No 1 (2020), 69–86. (with Daryl DeFord and Justin Solomon)

The Heisenberg group is pan-rational
Advances in Mathematics **346** (2019), 219–263. (with Michael Shapiro)

Random nilpotent groups I
IMRN, Vol 2018, Issue 7 (2018), 1921–1953. (with Matthew Cordes, Yen Duong, Meng-Che Ho, and Ayla Sánchez)

Hyperbolic groups
chapter in *Office Hours with a Geometric Group Theorist*, eds. M.Clay,D.Margalit, Princeton U Press (2017), 177–203.

Counting in groups: Fine asymptotic geometry
Notices of the American Mathematical Society **63**, No. 8 (2016), 871–874.

A sharper threshold for random groups at density one-half
Groups, Geometry, and Dynamics **10**, No. 3 (2016), 985–1005.
(with Katarzyna Jankiewicz, Shelby Kilmer, Samuel Lelièvre, John M. Mackay, and Ayla Sánchez)

Equations in nilpotent groups
Proceedings of the American Mathematical Society **143** (2015), 4723–4731. (with Hao Liang and Michael Shapiro)

Statistical hyperbolicity in Teichmüller space
Geometric and Functional Analysis, Volume 24, Issue 3 (2014), 748–795. (with Howard Masur and Spencer Dowdall)

Fine asymptotic geometry of the Heisenberg group
Indiana University Mathematics Journal 63 No. 3 (2014), 885–916. (with Christopher Mooney)

Pushing fillings in right-angled Artin groups
Journal of the LMS, Vol 87, Issue 3 (2013), 663–688. (with Aaron Abrams, Noel Brady, Pallavi Dani, and Robert Young)

Spheres in the curve complex
In the Tradition of Ahlfors and Bers VI, Contemp. Math. **590** (2013), 1–8. (with Howard Masur and Spencer Dowdall)

The sprawl conjecture for convex bodies
Experimental Mathematics, Volume 22, Issue 2 (2013), 113–122. (with Samuel Lelièvre and Christopher Mooney)

Filling loops at infinity in the mapping class group
Michigan Math. J., Vol 61, Issue 4 (2012), 867–874. (with Aaron Abrams, Noel Brady, Pallavi Dani, and Robert Young)

The geometry of spheres in free abelian groups
Geometriae Dedicata, Volume 161, Issue 1 (2012), 169–187. (with Samuel Lelièvre and Christopher Mooney)

Statistical hyperbolicity in groups
Algebraic and Geometric Topology **12** (2012) 1–18. (with Samuel Lelièvre and Christopher Mooney)

Length spectra and degeneration of flat metrics
Inventiones Mathematicae, Volume 182, Issue 2 (2010), 231–277. (with Christopher Leininger and Kasra Rafi)

Divergence of geodesics in Teichmüller space and the mapping class group
Geometric and Functional Analysis, Volume 19, Issue 3 (2009), 722–742. (with Kasra Rafi)

Curvature, stretchiness, and dynamics
In the Tradition of Ahlfors and Bers IV, Contemp. Math. **432** (2007), 19–30.

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Science, Technology, Law, and Policy Publications & Preprints

Models, Race, and the Law
Yale Law Journal Forum, Vol. 130 (March 2021). Available online. (with Doug Spencer)

Computational Redistricting and the Voting Rights Act
Election Law Journal, Available online. (with Amariah Becker, Dara Gold, and Sam Hirsch)

Discrete geometry for electoral geography
Preprint. (with Bridget Eileen Tenner) arXiv:1808.05860

Implementing partisan symmetry: Problems and paradoxes
Political Analysis, to appear. (with Daryl DeFord, Natasha Dhamankar, Mackenzie McPike, Gabe Schoenbach, and Ki-Wan Sim) arXiv:2008:06930

Clustering propensity: A mathematical framework for measuring segregation
Preprint. (with Emilia Alvarez, Everett Meike, and Marshall Mueller; appendix by Tyler Piazza)

Locating the representational baseline: Republicans in Massachusetts
Election Law Journal, Volume 18, Number 4, 2019, 388–401.
(with Taissa Gladkova, Eugene Henninger-Voss, Ben Klingensmith, Heather Newman, and Hannah Wheelen)

Redistricting reform in Virginia: Districting criteria in context
Virginia Policy Review, Volume XII, Issue II, Spring 2019, 120–146. (with Daryl DeFord)

Geometry v. Gerrymandering
The Best Writing on Mathematics 2019, ed. Mircea Pitici. Princeton University Press.
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Gerrymandering metrics: How to measure? What's the baseline?
Bulletin of the American Academy for Arts and Sciences, Vol. LXII, No. 2 (Winter 2018), 54–58.

Rebooting the mathematics of gerrymandering: How can geometry track with our political values?
The Conversation (online magazine), October 2017. (with Peter Levine)

A formula goes to court: Partisan gerrymandering and the efficiency gap
Notices of the American Mathematical Society **64** No. 9 (2017), 1020–1024. (with Mira Bernstein)

International mobility and U.S. mathematics
Notices of the American Mathematical Society **64**, No. 7 (2017), 682–683.

Graduate Advising in Mathematics

Nate Fisher (PhD 2021), Sunrose Shrestha (PhD 2020), Ayla Sánchez (PhD 2017), Kevin Buckles (PhD 2015), Mai Mansouri (MS 2014)

Outside committee member for Chris Coscia (PhD 2020), Dartmouth College

Postdoctoral Advising in Mathematics

Principal supervisor Thomas Weighill (2019–2020)

Co-supervisor Daryl DeFord (MIT 2018–2020), Rob Kropholler (2017–2020), Hao Liang (2013–2016)

Teaching

Courses Developed or Customized

Mathematics of Social Choice | sites.tufts.edu/socialchoice
Voting theory, impossibility theorems, redistricting, theory of representative democracy, metrics of fairness.

History of Mathematics | sites.tufts.edu/histmath
Social history of mathematics, organized around episodes from antiquity to present. Themes include materials and technologies of creation and dissemination, axioms, authority, credibility, and professionalization. In-depth treatment of mathematical content from numeration to cardinal arithmetic to Galois theory.

Reading Lab: Mathematical Models in Social Context | sites.tufts.edu/models
One hr/wk discussion seminar of short but close reading on topics in mathematical modeling, including history of psychometrics; algorithmic bias; philosophy of statistics; problems of model explanation and interpretation.

Geometric Literacy
Module-based graduate topics course. Modules have included: p-adic numbers, hyperbolic geometry, nilpotent geometry, Lie groups, convex geometry and analysis, the complex of curves, ergodic theory, the Gauss circle problem.

Markov Chains (graduate topics course)
Teichmüller Theory (graduate topics course)
Fuchsian Groups (graduate topics course)
Continued Fractions and Geometric Coding (undergraduate topics course)
Mathematics for Elementary School Teachers

Standard Courses

Discrete Mathematics, Calculus I-II-III, Intro to Proofs, Linear Algebra, Complex Analysis, Differential Geometry, Abstract Algebra, Graduate Real Analysis, Mathematical Modeling and Computation

Weekly Seminars Organized

- Geometric Group Theory and Topology
- Science, Technology, and Society Lunch Seminar

Selected Talks and Lectures

Distinguished Plenary Lecture — June 2021
75th Anniversary Meeting of Canadian Mathematical Society, Ottawa, Ontario — *online (COVID)*

BMC/BAMC Public Lecture — April 2021
Joint British Mathematics/Applied Mathematics Colloquium, Glasgow, Scotland — *online (COVID)*

AMS Einstein Public Lecture in Mathematics — [March 2020]
Southeastern Sectional Meeting of the AMS, Charlottesville, VA — *postponed*

Gerald and Judith Porter Public Lecture
AMS-MAA-SIAM, Joint Mathematics Meetings, San Diego, CA — January 2018

Mathematical Association of America Distinguished Lecture
MAA Carriage House, Washington, DC — October 2016

American Mathematical Society Invited Address
AMS Eastern Sectional Meeting, Brunswick, ME — September 2016

Named University Lectures

- Parsons Lecture | UNC Asheville — October 2020
- Loeb Lectures in Mathematics | Washington University in St. Louis — [March 2020]
- Math, Stats, CS, and Society | Macalester College — October 2019
- MRC Public Lecture | Stanford University — May 2019
- Freedman Memorial Colloquium | Boston University — March 2019
- Julian Clancy Frazier Colloquium Lecture | U.S. Naval Academy — January 2019
- Barnett Lecture | University of Cincinnati — October 2018
- School of Science Colloquium Series | The College of New Jersey — March 2018
- Kieval Lecture | Cornell University — February 2018
- G. Milton Wing Lectures | University of Rochester — October 2017
- Norman Johnson Lecture | Wheaton College — September 2017
- Dan E. Christie Lecture | Bowdoin College — September 2017

Math/Computer Science Department Colloquia

- Reed College — Dec 2020
- Georgetown (CS) — Sept 2020
- Santa Fe Institute — July 2020
- UC Berkeley — Sept 2018
- Brandeis-Harvard-MIT-NEU — Mar 2018
- Northwestern University — Oct 2017
- University of Illinois — Sept 2017
- University of Utah — Aug 2017
- Wesleyan — Dec 2016
- Worcester Polytechnic Inst. — Dec 2016
- Université de Neuchâtel — Jun 2016
- Brandeis University — Mar 2016
- Swarthmore College — Oct 2015
- Bowling Green — May 2015
- City College of New York — Feb 2015
- Indiana University — Nov 2014
- the Technion — Oct 2014
- Wisconsin–Madison — Sept 2014
- Stony Brook — March 2013

Minicourses

- Integer programming and combinatorial optimization (two talks) | Georgia Tech — May 2021
- Workshop in geometric topology (main speaker, three talks) | Provo, UT — June 2017
- Growth in groups (two talks) | MSRI, Berkeley, CA — August 2016
- Hyperbolicity in Teichmüller space (three talks) | Université de Grenoble — May 2016
- Counting and growth (four talks) | IAS Women's Program, Princeton — May 2016
- Nilpotent groups (three talks) | Seoul National University — October 2014
- Sub-Finsler geometry of nilpotent groups (five talks) | Galatasaray Univ., Istanbul — April 2014

Science, Technology, and Society

- The Mathematics of Accountability | Sawyer Seminar, Anthropology, Johns Hopkins — February 2020
- STS Circle | Harvard Kennedy School of Government — September 2019
- Data, Classification, and Everyday Life Symposium | Rutgers Center for Cultural Analysis — January 2019
- Science Studies Colloquium | UC San Diego — January 2019
- Arthur Miller Lecture on Science and Ethics | MIT Program in Science, Tech, and Society — November 2018

Data Science, Computer Science, Quantitative Social Science

- Data Science for Social Good Workshop (DS4SG) | Georgia Tech (virtual) — November 2020
- Privacy Tools Project Retreat | Harvard (virtual) — May 2020
- Women in Data Science Conference | Microsoft Research New England — March 2020
- Quantitative Research Methods Workshop | Yale Center for the Study of American Politics — February 2020
- Societal Concerns in Algorithms and Data Analysis | Weizmann Institute — December 2018
- Quantitative Collaborative | University of Virginia — March 2018
- Quantitative Social Science | Dartmouth College — September 2017
- Data for Black Lives Conference | MIT — November 2017

Political Science, Geography, Law, Democracy, Fairness

- The Long 19th Amendment: Women, Voting, and American Democracy | Radcliffe Institute — Nov–Dec 2020
- "The New Math" for Civil Rights | Social Justice Speaker Series, Davidson College — November 2020
- Math, Law, and Racial Fairness | Justice Speaker Series, University of South Carolina — November 2020
- Voting Rights Conference | Northeastern Public Interest Law Program — September 2020
- Political Analysis Workshop | Indiana University — November 2019
- Program in Public Law Panel | Duke Law School — October 2019
- Redistricting 2021 Seminar | University of Chicago Institute of Politics — May 2019
- Geography of Redistricting Conference Keynote | Harvard Center for Geographic Analysis — May 2019
- Political Analytics Conference | Harvard University — November 2018
- Cyber Security, Law, and Society Alliance | Boston University — September 2018
- Clough Center for the Study of Constitutional Democracy | Boston College — November 2017
- Tech/Law Colloquium Series | Cornell Tech — November 2017
- Constitution Day Lecture | Rockefeller Center for Public Policy, Dartmouth College — September 2017

Editorial Boards

Harvard Data Science Review
Associate Editor — since 2019

Advances in Mathematics
Member, Editorial Board — since 2018

Selected Professional and Public Service

Amicus Brief of Mathematicians, Law Professors, and Students 2019
principal co-authors: Guy-Uriel Charles and Moon Duchin
Supreme Court of the United States, in Rucho v. Common Cause - cited in dissent

Committee on Science Policy 2020–2023
American Mathematical Society

Program Committee 2020–2021
Symposium on Foundations of Responsible Computing

Presenter on Public Mapping, Statistical Modeling 2019, 2020
National Conference of State Legislatures

Committee on the Human Rights of Mathematicians 2016–2019
American Mathematical Society

Committee on The Future of Voting: Accessible, Reliable, Verifiable Technology 2017–2018
National Academies of Science, Engineering, and Medicine

Visiting Positions and Residential Fellowships

Visiting Professor Department of Mathematics Fall 2021
Boston College | Chestnut Hill, MA

Fellow Radcliffe Institute for Advanced Study 2018–19
Harvard University | Cambridge, MA

Member Center of Mathematical Sciences and Applications 2018–19
Harvard University | Cambridge, MA

Visitor Microsoft Research Lab 2018–19
MSR New England | Cambridge, MA

Research Member Geometric Group Theory program Fall 2016
Mathematical Sciences Research Institute | Berkeley, CA

Research Member Random Walks and Asymptotic Geometry of Groups program Spring 2014
Institut Henri Poincaré | Paris, France

Research Member Low-dimensional Topology, Geometry, and Dynamics program Fall 2013
Institute for Computational and Experimental Research in Mathematics | Providence, RI

Research Member Geometric and Analytic Aspects of Group Theory program May 2012
Institut Mittag-Leffler | Stockholm, Sweden

Research Member Quantitative Geometry program Fall 2011
Mathematical Sciences Research Institute | Berkeley, CA

Postdoctoral Fellow Teichmüller "project blanc" Spring 2009
Agence Nationale de la Recherche (Collège de France) | Paris, France

Exhibit 2

Response Report on Congressional Districting Plans in Pennsylvania

Moon Duchin
Professor of Mathematics, Tufts
University Senior Fellow, Tisch College of Civic Life

January 26, 2022

Response Report on Congressional Districting Plans in Pennsylvania

Moon Duchin
Professor of Mathematics, Tufts University
Senior Fellow, Tisch College of Civic Life

January 26, 2022

1 Assignment and qualifications

I am a Professor of Mathematics and a Senior Fellow in the Jonathan M. Tisch College of Civic Life at Tufts University. At Tisch College, I am the principal investigator of an interdisciplinary research lab focused on geometric and computational aspects of redistricting. I was recently awarded a major grant from the National Science Foundation to study *Network Science of Census Data*. My areas of research and teaching include the structure of census data, the design and implementation of randomized algorithms for generating districting plans, and the analysis of partisan fairness and of redistricting more broadly.

I have previously submitted a report in this case, and this report is in response to the filings of January 24, 2022.

2 Overview of plans

In my previous report, I compared three 17-district plans:

- `HB-2146`– derived from a plan by Amanda Holt, modified and then passed by the House of Representatives on Jan 12, 2022 and now by the Senate on Jan 24, 2022;
- `CitizensPlan`– derived from citizen-submitted contest entries in the Draw the Lines PA competition; and
- `GovPlan`– developed by the Governor's office, derived from submissions to a public portal.

To these I will add ten other plans that were submitted to the Commonwealth Court on January 24, 2022.

- `Carter`– plan by Carter petitioner group, developed by Dr. Jonathan Rodden using a least-change principle;
- `Gressman/GMS`– plan by Gressman petitioner group, developed through mathematical optimization techniques;
- `HouseDemCaucus`– plan by House Democratic Caucus;
- `SenateDemCaucus1`– first plan by Senate Democratic Caucus;
- `SenateDemCaucus2`– second plan by Senate Democratic Caucus;
- `Reschenthaler1`– first plan by Congressman Reschenthaler et al.;

- Reschenthaler2– second plan by Congressman Reschenthaler et al.;
- CitizenVoters– plan by "Citizen Voters" amici;
- VotersOfPA– plan by "Voters of the Commonwealth of Pennsylvania" amici;
- KhalifAli– plan by Khalif Ali et al. on behalf of the Public Interest Law Center.

3 An excellence standard for traditional criteria

Redistricting is not a literal optimization problem; if one plan splits an additional county with respect to another, it need not be disqualified, because plans are made in view of many legitimate, competing, and sometimes qualitative goals.[1] Even if we desired to seek literal optimization, there is no standard or universal way to optimize several factors at once. And even if we wanted to prioritize, say, compactness, we are still left with dozens of different compactness metrics and a question of how to aggregate them over a 17-district plan. The quantitative metrics describing traditional redistricting principles are helpful but not dispositive in our search for the best and fairest plan available.

Rather, the traditional/neutral principles serve as "a 'floor' of protection," in the words of the LWV decision. This means that if we can identify a level that constitutes *excellent* alignment with traditional principles, we should treat this as a threshold after which we may legitimately consider other aspects of a plan in coming to an ultimate selection.

3.1 Plans meeting the excellence standard for traditional criteria

All 13 plans are contiguous, and all 13 plans are closely population-balanced for either Census PL population or prisoner-adjusted population. This means that the neutral criteria most relevant for distinguishing the plans are **compactness** and **respect for counties and municipalities**.

I have based my review of six compactness metrics: five contour-based metrics named by the Court in 2018 and one discrete metric.

Table 1: Comparison of compactness and splitting metrics.

name	mean Polsby	mean Schwartz	mean Reock	mean ConvHull	mean PopPoly	cut edges	split counties	county pieces	split munis	muni pieces
GovPlan	0.3808	1.6534	0.4313	0.8257	0.7834	5185	16	35	18	37
CitizensPlan	0.3785	1.6625	0.4512	0.8120	0.7725	5237	14	30	16	33
HB-2146	0.3212	1.8197	0.4087	0.7987	0.7524	5907	15	33	16	34
Carter	0.3214	1.8103	0.4499	0.7922	0.7416	5926	14	31	20	41
Gressman/GMS	0.3478	1.7351	0.4261	0.8176	0.7582	5582	15	32	16	33
HouseDemCaucus	0.2787	1.9693	0.4286	0.7717	0.7205	6853	16	34	18	37
SenateDemCaucus1	0.3147	1.8144	0.4137	0.7918	0.7519	6047	17	36	19	39
SenateDemCaucus2	0.3346	1.7478	0.4146	0.8153	0.7601	5505	16	34	16	33
Reschenthaler1	0.3629	1.6859	0.4347	0.8238	0.7737	5090	13	29	16	33
Reschenthaler2	0.3524	1.7127	0.4231	0.8161	0.7658	5237	13	29	16	33
CitizenVoters	0.3490	1.7133	0.4412	0.8082	0.7575	5173	14	31	16	33
VotersOfPA	0.3965	1.6069	0.4697	0.8209	0.7681	5052	15	31	18	37
KhalifAli	0.3523	1.7204	0.4448	0.8111	0.7456	5266	16	35	18	37

By far the two most compact plans, considering these metrics overall, are VotersOfPA and GovPlan. The next two, some ways behind the leaders, are Reschenthaler1 and CitizensPlan.

When it comes to splits, I judge all of the plans to be excellent, with the possible exception of Carter and SenateDemCaucus1. All eleven others have 13-16 county splits and 16-18 municipality splits, which may be close to optimal for reasonable 17-district plans in Pennsylvania (though it is computationally intractable to prove this rigorously).

[1] Optimization techniques may, of course, still be highly helpful for finding valuable examples of plans.

Therefore I judge that plans that meet a high excellence standard for traditional criteria are

- `GovPlan`
- `VotersOfPA`
- `Reschenthaler1`
- `CitizensPlan`

The next tier of plans meeting an excellence standard for traditional criteria are

- `KhalifAli`
- `Reschenthaler2`

4 Partisan fairness does not require loosening neutral criteria

4.1 Using election data

To understand partisan fairness in the context of the range of electoral conditions in Pennsylvania, it is crucial to observe a range of voting behavior in the state. This is why creating a "voting index" or "election blend" is highly inadvisable. To illustrate this, consider for example a state like Massachusetts, in which Senate and Presidential elections are strongly Democratic (with something like a 2-to-1 ratio) and Governor elections are sometimes strongly Republican (approaching a 2-to-1 ratio in the other direction). If you simply averaged these, you would produce an index that looks "purple," with many precincts evenly split between a Democratic and Republican preference—a pattern that never actually occurs in the state.

This means that there are two options for a responsible modeler: either show observed elections serially, one at a time and not averaged, so that the local effects of incumbency and office and national climate can be considered in assessing the pattern, or study how and whether the Congressional voting patterns do in fact resemble a statewide average, and how they differ. Of the expert reports assessing partisan fairness, I have taken the former approach, along with Daryl DeFord, and Jonathan Rodden has taken the latter approach.

Michael Barber's report does neither, basing the bulk of his analysis on a blend of elections and even applying a swing to the election mix rather than regarding the actual observed elections serially.[2]

[2] A corollary of this blending approach, especially under the time constraints of a compressed court schedule, is that the accuracy of his results is harder to audit. But in at least one case he is clearly in error. Dr. Barber reports that CD 16 (Erie) in HB-2146 is a swing district—that is, it is sometimes won by the Democrat and sometimes by the Republican across the 11 elections in his principal dataset. This is false—this district went for the Republican in 11 out of 11 elections. Even in the Governor's race of 2018, in which the Democratic candidate achieved nearly 59% share statewide, this district had more votes for the Republican. Since this is one of only a few cases in which there was enough information to audit Dr. Barber's report for accuracy, I assume there are many similar errors in the handling of electoral data.

4.2 Overview of partisan performance by election

Table 2: Partisan outcomes (number of D seats) by election.

Plan	GOV14	AG16	AUD16	PRES16	SEN16	TRES16	GOV18	SEN18	AG20	AUD20	PRES20	TRES20
GovPlan	10	10	8	9	6	10	11	11	10	8	9	9
CitizensPlan	10	10	7	8	6	10	11	10	10	7	9	8
HB-2146	9	7	7	7	5	10	10	10	10	5	8	7
Carter	10	10	8	8	6	10	11	11	10	7	9	9
Gressman/GMS	10	10	8	8	9	10	11	10	10	8	9	8
HouseDemCaucus	10	10	8	8	6	10	11	11	11	8	10	9
SenateDemCaucus1	10	9	8	7	7	9	11	11	10	7	9	7
SenateDemCaucus2	10	10	8	9	7	10	11	10	10	8	9	9
Reschenthaler1	9	6	7	7	5	8	10	9	9	6	8	7
Reschenthaler2	9	6	7	7	5	8	10	9	9	6	8	7
CitizenVoters	9	9	8	8	5	10	11	10	10	7	8	8
VotersOfPA	9	8	8	8	5	10	11	9	10	6	8	8
KhalifAli	9	8	9	7	7	10	11	11	10	6	9	7

4.3 Plans dominating the field under partisan fairness metrics

Table 3: Comparison of all plans under four metrics of fairness in the economics and political science literature.

	total efficiency gap	total Eguia metric	total mean-median	total partisan bias
GovPlan	0.1007	−0.0486	−0.0077	−0.1176
CitizensPlan	−0.1678	−0.3427	−0.1042	−0.6471
HB-2146	−0.8336	−0.9898	−0.2927	−1.2353
Carter	−0.0058	−0.1663	−0.113	−0.5294
Gressman/GMS	0.1394	−0.0486	−0.0385	−0.2353
HouseDemCaucus	0.1814	0.0102	−0.0071	0.1765
SenateDemCaucus1	−0.2601	−0.4015	−0.1382	−0.7059
SenateDemCaucus2	0.1221	−0.0486	0.0106	0.1176
Reschenthaler1	−1.1024	−1.2251	−0.2524	−1.1176
Reschenthaler2 2	−1.1042	−1.2251	−0.2534	−1.0588
CitizenVoters	−0.4074	−0.5192	−0.1847	−0.6471
VotersOfPA	−0.5686	−0.6957	−0.2734	−0.8824
KhalifAli	−0.3166	−0.4604	−0.1209	−0.4706
ensemble mean	−0.6755	−0.8451	−0.2872	−1.1437

In the study of optimizing multiple objectives, we say that one data point **dominates** another if it is equal or better in every metric. A data point that is not dominated by any other is on the *Pareto frontier* of the dataset.

Of the twelve other plans, the Governor's Plan dominates 10 and is in a trade-off position with the other two (Carter and HouseDemCaucus). No plan dominates the Governor's plan. From this "Pareto frontier" perspective, the Governor's plan is the strongest in the field.[3]

[3]Of these four metrics, three have been subjected to much more scrutiny in the peer-reviewed literature, with Eguia's metric being newer and less tested. If you throw out the Eguia metric and restrict to the three better-established ones, the list of dominating plans is unchanged.

5 Conclusion

Most of the plans before the court are very good on the traditional districting principles and would be well over the line to be considered for adoption under normal circumstances. Even if a standard of *excellence* is imposed on the neutral criteria, I find four plans (`GovPlan`, `VotersOfPA`, `Reschenthaler1`, and `CitizensPlan`) to be in the top tier, followed by two more (`KhalifAli`, `Reschenthaler2`). Many of the others, I emphasize, are also very strong.

But among those that meet the quality standards for the neutral criteria, we are not required to choose by a beauty contest of numerical optimization. Instead, we should rightly consider factors like whether community input was meaningfully incorporated into the plan design and whether the ultimate effect of the plan will be one of treating the political parties fairly and even-handedly.

In partisan terms, a multi-optimization framework applied to traditional scores of partisan fairness would identify three plans—`GovPlan`, `Carter`, and `HouseDemCaucus`—as dominating the field.

Therefore it is my conclusion that the Governor's plan is an excellent choice (though not the only reasonable choice) as the best plan before the Court.