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IN THE COMMONWEALTH COURT OF PENNSYLVANIA

<p>CAROL ANN CARTER; MONICA PARRILLA; REBECCA POYOUROW; WILLIAM TUNG; ROSEANNE MILAZZO; BURT SIEGEL; SUSAN CASSANELLI; LEE CASSANELLI; LYNN WACHMAN; MICHAEL GUTTMAN; MAYA FONKEU; BRADY HILL; MARY ELLEN BALCHUNIS; TOM DEWALL; STEPHANIE MCNULTY; and JANET TEMIN,</p> <p style="text-align: center;">Petitioners,</p> <p style="text-align: center;">v.</p> <p>LEIGH M. CHAPMAN, in her official capacity as the Acting Secretary of the Commonwealth of Pennsylvania; JESSICA MATHIS, in her official capacity as Director for the Pennsylvania Bureau of Election Services and Notaries,</p> <p style="text-align: center;">Respondents.</p>	<p>No. 464 MD 2021</p>
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No. 464 MD 2021

<p>PHILIP T. GRESSMAN; RON Y. DONAGI; KRISTOPHER R. TAPP; PAMELA GORKIN; DAVID P. MARSH; JAMES L. ROSENBERGER; AMY MYERS; EUGENE BOMAN; GARY GORDON; LIZ MCMAHON; TIMOTHY G. FEEMAN; and GARTH ISAAK,</p> <p style="text-align: center;">Petitioners,</p>	<p>No. 465 MD 2021</p>
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No. 465 MD 2021

v.

LEIGH M. CHAPMAN, in her official capacity as the Acting Secretary of the Commonwealth of Pennsylvania; JESSICA MATHIS, in her official capacity as Director for the Pennsylvania Bureau of Election Services and Notaries,

Respondents.

**GOVERNOR WOLF'S BRIEF IN SUPPORT OF
PROPOSED 17-DISTRICT CONGRESSIONAL REDISTRICTING PLAN**

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Intervenor-Respondent Tom Wolf, Governor of the Commonwealth of Pennsylvania, submits this Brief in support of his Proposed 17-District Congressional Redistricting Plan (the “Plan”).

INTRODUCTION

Congressional redistricting is not merely a once-in-a-decade exercise in adjusting boundary lines on a map. It is a question of fundamental fairness that has profound consequences for the health of our democracy. As our Supreme Court observed in its seminal decision in *League of Women Voters v. Commonwealth*, 178 A.3d 737 (Pa. 2018) (“*League of Women Voters I*”), “a healthy representative democracy” requires that “all voters ... have an equal opportunity to translate their votes into representation.” *Id.* at 814. By contrast, a district map that entrenches structural partisan advantage, produces the same electoral results irrespective of changes in voter preferences, and systematically awards more than 50% of the seats to a party winning less than 50% of the votes, “discourages voters from participating in the electoral process.” *Id.* Such a map—which has been seen all too often in the history of the Commonwealth—yields a government that is neither responsive nor accountable to Pennsylvania voters.

Governor Wolf is the only party to this litigation who has a constituency of, and thus represents the interests of, *all* Pennsylvania voters. And no other party in the litigation—and, indeed, no one else in the Commonwealth—shares the

Governor’s authority to approve or veto a proposed congressional district map. In that unique capacity, the Governor submits a Proposed Congressional District Plan (the “Plan”) that is fair, evenhanded, and consistent in every respect with state and federal law.

League of Women Voters I recognized that there are well-established traditional redistricting criteria that help advance the goal of fairness. By every single one of those metrics—compactness, contiguity, minimization of division of political subdivisions, and maintenance of population equality among congressional districts—the Governor’s Plan is exemplary. As our Supreme Court has acknowledged, however, although satisfying these traditional criteria is a prerequisite, a truly fair and level political playing field often requires more. The Governor’s Plan answers this call, realizing all of the fundamental redistricting goals recognized by *League of Women Voters*: The Plan maintains cohesive communities of interest; preserves the cores of the pre-existing congressional districts; avoids entrenching partisan advantage; and ensures that elected representatives will be responsive and accountable to Pennsylvania voters. By adopting the Governor’s Plan, the Court will maintain free and equal elections, provide every Pennsylvanian fair and equal representation in the United States House of Representatives, and vindicate the “core principle of our republican form

of government[:] ‘that the voters should choose their representatives, not the other way around.’” *Id.* at 740-41 (citation omitted).

BACKGROUND

In the ordinary course of events, Pennsylvania’s congressional districts “are drawn by the state legislature as a regular statute, subject to veto by the Governor.” *League of Women Voters I*, 178 A.3d at 742. In 2018, after holding that Pennsylvania’s then-operative congressional district map—signed into law before Governor Wolf took office—was an unlawful partisan gerrymander that violated the Pennsylvania Constitution, *see League of Women Voters I*, 178 A.3d at 821, the Pennsylvania Supreme Court drew Pennsylvania’s current congressional district map (“the 2018 Remedial Plan”) using data from the 2010 Census. *See League of Women Voters of Pa. v. Commonwealth*, 181 A.3d 1083, 1086 (Pa. 2018) (“*League of Women Voters II*”).

In 2020, the United States Census Bureau conducted the constitutionally required decennial census. *See* U.S. Const. art. I, § 2. The Census Bureau released redistricting data to Pennsylvania on August 12, 2021.¹ Nonetheless, as of the time this brief was finalized—with the first deadlines in the primary election calendar imminent—the General Assembly has not passed a proposed congressional district

¹ *See* United States Census Bureau, *Redistricting Data Datasets*, <https://www.census.gov/programs-surveys/decennial-census/data/datasets/rdo.html>.

map, and the Governor has therefore not had the opportunity to approve or disapprove any map presented to him.

While waiting for action by the General Assembly, 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 redistricting experts formed to provide guidance to the Governor and assist his review of any congressional redistricting plan passed by the General Assembly.² At the same time, Governor Wolf announced the opening of a redistricting website at which members of the public could submit proposed maps, outline communities of interest, and submit comments to help shape the outcome of this critical part of our democratic process.³ The Redistricting Council 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 map passed by the General Assembly.

² 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/>.

³ 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/>.

These Redistricting Principles, derived from Pennsylvania and U.S. Supreme Court precedent, were finalized by the Council and made public by the Governor on November 24, 2021.⁴ Further, during the General Assembly’s deliberations, the Governor has provided public feedback on proposed maps,⁵ and publicly highlighted two redistricting maps as examples 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.⁶

Now, at this late hour in the election calendar, the General Assembly has all but run out of time to pass a congressional district map for the Governor’s consideration. Although the Pennsylvania House of Representatives has passed a proposed congressional redistricting plan (the “House Map”), *see* H.B. 2146, Reg. Sess. 2021-2022 (passed by the House on January 12, 2022, by a 110-to-91 vote,

⁴ *See* Pennsylvania Redistricting Advisory Council, *Redistricting Principles*, <https://www.governor.pa.gov/wp-content/uploads/2021/11/Redistricting-Advisory-Council-Final-Principles.pdf>.

⁵ *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>.

⁶ *See* Governor Tom Wolf, *Congressional Districts Map Proposals* (Jan. 15, 2022), <https://www.governor.pa.gov/congressional-districts-map-proposals/>.

with all Democratic and two Republican members voting in opposition⁷), its fate in the Pennsylvania Senate is unclear. Unfortunately, the House Map is unacceptable for several fundamental reasons, as the Governor has publicly explained; it fundamentally fails to meet the test of fairness set forth by the Pennsylvania Supreme Court in *League of Women Voters I* and does not comply with the Redistricting Principles outlined by the Redistricting Advisory Council.⁸ Accordingly, even if the House Map passed the Senate, the Governor could not in good conscience sign it into law.⁹ Absent an unexpected last-second reversal by the General Assembly, it will be necessary for the Court to step in to adopt a new congressional district plan that ensures compliance with constitutional and statutory requirements and best protects the fair and equal representation of all Pennsylvanians.

⁷ See Details of House RCS No. 708, House Roll Calls, Pennsylvania House of Representatives (Jan. 12, 2022), 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.

⁸ See *supra* note 5; Governor Tom Wolf, *Gov. Wolf: Fair Congressional Maps are Possible, Highlights Gerrymander-Free Examples* (Jan. 15, 2022), <https://www.governor.pa.gov/newsroom/gov-wolf-fair-congressional-maps-are-possible-highlights-gerrymander-free-examples/#:~:text=Learn%20more.-,Gov.%20Wolf%3A%20Fair%20Congressional%20Maps%20are,Possible%2C%20Highlights%20Gerrymander%2DFree%20Examples&text=%E2%80%9CThroughout%20the%20congressional%20redistricting%20process,%2C%E2%80%9D%20said%20Gov.%20Wolf>.

⁹ See *id. supra* notes 5 and 8.

ARGUMENT

I. Congressional Reapportionment Is Governed by Well-Established Legal Principles

A. Pennsylvania Law Requires That a Congressional District Plan Meet a Number of Benchmark Criteria, Provide Voters a Fair and Equal Opportunity to Elect Candidates of Their Choice, and Avoid Entrenching Structural Partisan Advantage

Contained within the Pennsylvania Constitution’s Declaration of Rights, Article I, Section 5 of the Pennsylvania Constitution, the “Free and Equal Elections Clause,” is “an enumeration of the fundamental individual human rights possessed by the people of this Commonwealth that are specifically exempted from the powers of Commonwealth government to diminish.” *League of Women Voters I*, 178 A.3d at 803. The Clause states: “Elections shall be free and equal; and no power, civil or military, shall at any time interfere to prevent the free exercise of the right of suffrage.” Pa. Const. art. I, § 5.

In *League of Women Voters I*, the Pennsylvania Supreme Court rigorously analyzed the Free and Equal Elections Clause, examining its language, *see* 178 A.3d at 803-04; the relevant Pennsylvania history influencing the original drafting and evolution of the Clause, *id.* at 804-09; the Clause’s interpretation in Pennsylvania case law, *id.* at 809-13; and various other considerations, *id.* at 813-14. The Court concluded that the Clause (1) “should be given the broadest interpretation, one which governs all aspects of the electoral process”; (2) affords an affirmative right, by “provid[ing] the people of this Commonwealth an equally

effective power to select the representative of his or her choice”; and (3) imposes a negative prohibition, “bar[ring] the dilution of the people’s power to do so.” *Id.* at 814.

1. Pennsylvanians Have a Right to Select the Representatives of Their Choice on a Level Playing Field

Because the Free and Equal Elections Clause governs all aspects of the electoral process, it of course applies to redistricting. For a redistricting plan to respect voters’ right to choose their representatives on equal terms, it must satisfy certain “neutral benchmarks” that are “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.” *Id.* at 816. Those “neutral benchmarks” are whether the congressional districts created under a plan (1) are “composed of compact and contiguous territory”; (2) are “as nearly equal in population as practicable”; and (3) “do not divide any county, city, incorporated town, borough, township, or ward, except where necessary to ensure equality of population.” *Id.* at 816-17 (citation and quotation omitted).

The use of compactness, contiguity, and the maintenance of the integrity of the boundaries of political subdivisions maintains the strength of an individual’s vote in electing a congressional representative. When an individual is grouped with other members of his or her community in a congressional district for purposes of voting, the commonality of the interests shared with the other voters in the community increases the ability of the individual to elect a

congressional representative for the district who reflects his or her personal preferences.

Id. at 816. Further, the Court made clear that these benchmark criteria are not the sole test of whether, or to what degree, an actual or proposed congressional district plan meets the standard enshrined in the Free and Equal Elections Clause. In other words, application of these criteria does not exhaust the inquiry into whether, or to what degree, a given plan affords voters a fair and equal opportunity to translate popular support into legislative representation—or, conversely, operates to entrench structural partisan advantage. Instead, “[t]hese neutral criteria provide a ‘floor’ of protection for an individual against the dilution of his or her vote in the creation of such districts.” *Id.* at 817.

2. District Maps Must Not Dilute Pennsylvanians’ Power to Choose Their Representatives

In addition to endowing Pennsylvanians with the positive right to choose their representatives, the Free and Equal Elections Clause also prohibits redistricting plans from “unfairly dilut[ing] the power of a particular group’s vote for a congressional representative.” *Id.* In *League of Women Voters I*, the Court identified “unfair partisan political advantage” as one form of such prohibited vote dilution. *Id.* Similarly, in *Mellow v. Mitchell*, 607 A.2d 204 (Pa. 1992), the Court assessed whether the proposed map was “politically fair,” ultimately selecting a

map that “result[ed] in a politically fair balance in the Pennsylvania delegation between Democrats and Republicans.” *Id.* at 210.

Avoiding systematic or entrenched partisan advantage is thus a key goal of the Free and Equal Elections Clause. And that goal cannot be fully realized solely by ensuring satisfaction of the traditional redistricting criteria. As the Court cautioned in *League of Women Voters I*, “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.” 178 A.3d at 817.

B. The Constitution Protects the Principle of “One Person, One Vote”

Article I, Section 2 of the U.S. Constitution states that the members of the House of Representatives shall be chosen “by the People of the several States.” U.S. Const. art. I, § 2. A corollary of that constitutional command is that, “as nearly as is practicable[,] one man’s vote in a congressional election is to be worth as much as another’s.” *Wesberry v. Sanders*, 376 U.S. 1, 7-8 (1964). As the U.S. Supreme Court has held, the “as nearly as practicable” standard requires that the proponent of a map “make a good-faith effort to achieve precise mathematical equality. Unless population variances among congressional districts are shown to have resulted despite such effort, the State must justify each variance, no matter

how small.” *Kirkpatrick v. Preisler*, 394 U.S. 526, 530 (1969) (internal citation omitted); *accord Karcher v. Daggett*, 462 U.S. 725, 730 (1983).

There are several “consistently applied” state interests that “might justify some variance,” many of which overlap with the *League of Women Voters I* neutral benchmarks: “making districts compact, respecting municipal boundaries, preserving the cores of prior districts, and avoiding contests between incumbent Representatives.” *Karcher*, 462 U.S. at 740 (emphasis added). Additionally, “those legitimate considerations can include a state interest in maintaining ... the competitive balance among political parties.” *Harris v. Ariz. Indep. Redistricting Commn.*, 578 U.S. 253, 258 (2016) (citation omitted); *accord Mellow*, 607 A.2d at 208.

II. The Governor’s Proposed Plan Is Fair, Constitutional, and Respects the Criteria Set Forth by the Pennsylvania and U.S. Supreme Courts.

Applying state and federal constitutional law and redistricting principles, the merits of the Governor’s Plan are clear.

Today, district maps are analyzed in many different ways using many different metrics. That analysis requires sophisticated mathematical and algorithmic tools and well-qualified experts. For this reason, to assess potential remedial congressional districting maps and examine his Plan, Governor Wolf retained Dr. Moon Duchin of Tufts University, a renowned mathematician and redistricting expert. *See* Duchin Curriculum Vitae, Duchin Report, attached as

Exhibit A. Dr. Duchin was asked to use best practices from mathematics and statistics to examine congressional redistricting in Pennsylvania. *See* Ex. A, Duchin Report. As shown by district-by-district review and the analysis in Dr. Duchin’s Report, Governor Wolf’s Plan exemplifies the proposition, espoused in *League of Women Voters I*, 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.” 178 A.3d at 817-18. The Plan (1) easily satisfies the *League of Women Voters I* benchmark criteria, (2) abides by the prohibition on entrenching partisan advantage while, concomitantly, promoting small-“d” democratic responsiveness and accountability by affording voters a fair and equal opportunity to elect representatives reflecting their political preferences.

A. The Plan Respects Traditional Districting Principles

Reviewing the Plan on a district-by-district basis underscores that it creates congressional districts that are compact and contiguous, and that it uses rationally drawn boundaries that minimize splits while preserving communities of interest.

See League of Women Voters I, 178 A.3d at 816-17.

- 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.
- District 2 — The Great Northeast: Maintains the entirety of Northeast Philadelphia and North Philadelphia east of Broad Street, with the western and southern borders unchanged and linking with the similar suburban communities of Bensalem and Eddington. Interstate 95 and Roosevelt Boulevard (Rt. US-1) run through the district and SEPTA connects the district through multiple bus and train lines. This is an Opportunity District (in other words, Black and Latino voters make up a majority of voters in the district).
 - District 3 — Schuylkill East: District 3 unites the communities of Northwest and West Philadelphia and North Philadelphia west of Broad Street and Center City, largely along similar lines as the current district. The district picks up a small amount of additional needed population in Southwest and South Philadelphia, but largely maintains continuity with the existing District. This is a Majority-Black District (in other words, Black voters make up a majority of voters in the district).
 - District 4 — MontCo/Berks: District 4 includes the majority of Montgomery County, which has a fast-growing population that requires more than one district. Popular with commuters to Philadelphia or King of Prussia, the district includes the neighboring communities of Lower Merion, Abington, Cheltenham, Norristown, Upper Dublin, and Lower Providence. Like the 2018 Remedial Plan, District 4 includes a portion of Berks County.
 - District 5 — Southeast Corner: With all of Delaware County and portions of South Philadelphia and southern Montgomery County, these communities comprise the southeast border with New Jersey and Delaware. The region has the Philadelphia International Airport, which spans the county border, and industrial areas in Southwest Philadelphia, PhilaPort and the fast-growing Navy Yard, linking them with industrial and port facilities south of Philadelphia in Delaware County. To attain needed population, the

district expands slightly beyond its current area in Montgomery County along the Schuylkill River.

- District 6 — Keystone: Much like the 2018 Remedial Plan, District 6 connects Chester County and a portion of southern Berks County including Reading, the fourth largest city in Pennsylvania. Both counties have a rich history dating back to the founding of the commonwealth and contain significant state parks and green space. With Chester among the fastest growing counties in the state, and similarly strong population growth in Reading and the surrounding area, only slight adjustments are needed from the 2018 Remedial Plan. In the Public Comment Portal, numerous comments expressed a desire that Reading not be split—noting that Reading has grown in population and contains an expanding Latino population for which constituents wanted to have equitable representation. This map honors that request and keeps Reading whole.
- District 7 — The Lehigh Valley: This district comprises all of Lehigh and Northampton counties and southern Monroe County. Much like the existing district, this map has three third-class cities of Allentown, Bethlehem and Easton with their shared heritage of manufacturing and common interests. The district is crisscrossed by major intersecting highways including I-78, I-476 and the Lehigh Valley Thruway, Route 22, making this area an increasing warehousing and logistics hub, and spurring growth that landed Lehigh County in the top five fastest growing counties in the state over the past decade.
- District 8 — Mountain Northeast: District 8 centers around the cities of Scranton, Wilkes-Barre, and Hazleton. With all of Lackawanna, Pike, and Carbon counties, along with neighboring communities in Luzerne, Monroe, and Wayne counties, these communities share cultural and geographical similarities as part of the Pocono region. The outdoors and recreation are important to the region’s economy and lifestyle, with many state parks, forests, and game lands. The district includes fast-growing bedroom communities for New York City, and like District 7, is connected by major highways I-78, I-81, and I-476, offering access to both New York and Philadelphia population centers.

- District 9 — East Central: Connecting communities with common socio-economic and cultural interests, District 9 includes counties of the Northern Tier with adjoining counties to the south, as well as much of the North Branch of the Susquehanna River, with the exception of portions included in District 8 to avoid splitting Wilkes-Barre and Scranton. The district includes larger communities of Lebanon, Pottsville, Bloomsburg, Tunkhannock and Forest City.
- District 10 — Susquehanna Valley West: Extending west from the Susquehanna River, District 10 includes all of York and Adams counties, and eastern Cumberland County. This district shares a rich agricultural heritage and identity, even as the district's economy modernizes increasingly towards manufacturing and logistics. Close to the Maryland border and rich with Pennsylvania history, District 10 contains several interstates—I-81, I-83, I-76 and US 11/15—making it a busy corridor for the trucking industry, commuters, and visitors to central Pennsylvania creating ease of travel between counties, cities, boroughs, and townships. Residents of Cumberland, Adams and York counties share high quality K-12 schools and top-rated public and private colleges and universities, such as Dickinson, Gettysburg, York, Central Penn, and Penn State York. This region boasts farmland, state parks, ski resorts, and seasonal festivals, as well as a variety of industries from health care and retail to technology, and manufacturing.
- District 11 — Susquehanna Valley East: District 11 unites the fast-growing areas of Lancaster County with southern Dauphin County, including Harrisburg. Linked by Route 283, Amtrak's Keystone Service and the Turnpike, the counties have vibrant urban centers with significant cultural opportunities and restaurants, as well as suburban enclaves transitioning gradually to less dense agricultural areas and rich history in agriculture. The district is home to the State Capital, and various industries, including candy and confection giant The Hershey Company, major health care providers with Lancaster General Hospital and the Penn State Health Milton S. Hershey Medical Center, along with significant agricultural operations and small farms throughout. The Pennsylvania Redistricting Public Comment Portal received many

comments on how this area of the map should be drawn, a frequent comment concerned keeping Harrisburg whole and not connecting it with other counties to the north.

- District 12 — Ridge and Valley: This district comprises much of the same area as the current 13th District, but like other districts, has stretched eastward, following the ridge and valley geography of the Appalachians. District 12 includes the third-class city of Altoona and significant recreational areas including Raystown Lake, numerous large Game Land tracts, and State Parks and Forests.
- District 13 — Southwest Corner: District 13 combines the major energy-producing counties of Washington, Greene, Fayette, Somerset and Westmoreland, with their shared industries of gas exploration and mining, into one compact district in the southwest. The district unites businesses and families of the Mon Valley communities—with common interests and history—with communities to the east and west. Outdoor recreation with the Laurel Highlands and Great Allegheny Passage Trail is helping to drive tourism to the area. As with other areas of the map, the shifts in District 13 are driven by population shifts, with the addition of Somerset County as the district expands eastward to add needed population.
- District 14 — Pennsylvania Wilds: This district joins some of the most rural counties in Pennsylvania and is known for its tourism and outdoor assets, including the largest free-roaming elk herd in the northeastern United States, the Allegheny National Forest, the darkest skies on the East Coast, and several state parks and outdoor recreational opportunities. This district includes all of Warren, McKean, Potter, Tioga, Forest, Elk, Cameron, Clinton, Clarion, Jefferson, Clearfield, Centre, Armstrong, and Indiana counties as well as a portion of Lycoming County. The core of this district remains the same as the current 15th District but has shifted eastward due to population decline in the Northwest and North Central part of the state. The district includes Warren, Bradford, Coudersport, St. Marys, Emporium, Lock Haven, Clarion, Brookville, DuBois, Bellefonte, Parker, and Indiana. Multiple public comments from the Governor’s Redistricting Portal suggest

that Centre County not be divided, and District 14 honors that request by keeping Centre County whole.

- District 15 — The I-79 Corridor: District 15 includes Erie and counties to the south along the Ohio border to Lawrence and Butler counties. For the western tip of Pennsylvania, manufacturing, retail trade, and health care and social assistance are among the largest employers. From shipping ports and vineyards to hiking and biking trails, the northern I-79 corridor of the Lake Erie region bordering Ohio and New York includes counties that are designated transitional as their economic status. As with other areas of the map, the shifts in District 15 are responses to population changes by adding Venango County, and most of Butler County, which was divided nearly in half under the 2018 Remedial Plan. The district expands eastward to add needed population. District 15 includes Erie, along with other communities, including Meadville, Titusville, Oil City, Franklin, Sharon, and New Castle.

- District 16 — Allegheny West: Unites Beaver County with western Allegheny County, including part of Pittsburgh and a small part of Butler County. Rich with a history in manufacturing along the Ohio River and throughout the region, the District is transforming with smaller manufacturing and service industries. This configuration was modelled on the original Draw the Lines Pennsylvania Citizens' Map. In evaluating the 1,500 submissions that contributed to the Citizens' Map, Draw the Lines found that many mappers created a clear line of demarcation between Beaver County and Washington County and put Butler County in a district with Erie. They thus adopted these preferences and divided Pittsburgh to ensure that there would only be a single county split in Allegheny County.

- District 17 — Allegheny East: Connects the eastern portion of Pittsburgh to the eastern suburbs along the Parkway East and south to the entrance to the upper Mon Valley and a portion of Westmoreland County. This map recognizes the decades-long economic connection of these communities and the area's evolving

technology sector along with strong educational and medical institutions.

1. Population Equality

All districts in the Governor’s Plan are essentially equal in population. The difference in population between the largest and smallest of Pennsylvania’s 17 Congressional Districts—known as population deviation—under the Governor’s Plan is one person, guaranteeing perfect compliance with the fundamental precept of “one person, one vote.” Ex. A, Duchin Report at 8. In other words, no district has more than 764,865 persons and no district has fewer than 764,864 persons (Pennsylvania’s total population divided by 17 congressional districts).¹⁰

2. Compactness and Contiguity

Like those in the 2018 Remedial Plan, the districts in the Governor’s Plan are compact. Changes in the Governor’s Plan from the 2018 Remedial Plan are driven by population shifts in the 2020 Census, which saw 44 counties—including particularly those in the West and North area of the state—losing population, while the remaining 23 counties—predominantly but not exclusively in the Southeast—gained population.¹¹ The Governor’s Plan responds to these shifts in population—

¹⁰ Governor Wolf’s Plan is drawn to achieve population equality under both the census PL94-171 dataset and LRC dataset #1. The expert report submitted in support of the Governor’s Plan also presents population balance figures using LRC dataset #2.

¹¹ See Census 2020 Redistricting Data, Pennsylvania State Data Center, <https://pasdc.hbg.psu.edu/> (last accessed January 24, 2022).

and the consequent loss of a Congressional seat—in a natural way by expanding districts beginning in the northwest to encompass additional population.

Dr. Duchin’s analysis further confirms the Plan’s compactness. There are three metrics that are commonly used to assess compactness: the Polsby-Popper score, the Reock score, and Voting District (“VTD”) cut edges. A map’s Polsby-Popper score is “the isoperimetric ratio comparing a region’s area to its perimeter, via the formula $4uA/P^2$. Higher scores are considered more compact, with circles uniquely achieving the optimum score of 1.” Ex. A, Duchin Report at 5. The Reock score provides 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.” *Id.* And VTD cut edges measures “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?” *Id.* at 6.

As shown in the following chart, the Governor’s Plan not only is quantitatively compact, but it is also *more* compact than other redistricting plans, including the plan passed by the Pennsylvania House of Representatives.

	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

Id. at 9.

The districts in the Plan are also contiguous: all parts of each district are in contact with another part of the district and no part of any district is connected at a narrow single point. In other words, the Plan is the antithesis of the “Rorschachian and sprawling” map denounced in *League of Women Voters I*. 178 A.3d at 819.

3. Avoiding County Splits

The Governor’s Plan splits only 16 counties, which is comparable to the splits in the Supreme Court’s 2018 Remedial Plan—splitting 13 counties, *see* 181 A.3d at 1087—and the plan adopted by the Court in *Mellow*, which had 19 county splits. 607 A.2d at 208. Here, the county splits were necessary to (1) adjust for the fact that Philadelphia and Allegheny counties each have populations too large to subsume in a single congressional district, and (2) ensure equal population across all districts, as required by Pennsylvania and U.S. Supreme Court precedent.

4. Protecting Communities of Interest

As shown in the district-by-district descriptions above, the Governor’s Plan reflects carefully considered decisions to ensure that cohesive communities of interest are preserved. In *League of Women Voters I*, the Court emphasized that

reapportionment ought to create “representational districts that ... maintain the geographical and social cohesion of the communities in which people live and conduct the majority of their day-to-day affairs[.]” 178 A.3d at 814. “When an individual is grouped with other members of his or her community in a congressional district for purposes of voting, the *commonality of the interests shared with the other voters in the community* increases the ability of the individual to elect a congressional representative for the district who reflects his or her personal preferences.” *Id.* at 816 (emphasis added). This precept is neither new to Pennsylvania law—36 years before *League of Women Voters I*, the Court in *Mellow* spoke approvingly of preserving communities of interest, *see* 607 A.2d at 208, 216—nor unique to it. The U.S. Supreme Court has similarly recognized that preserving the integrity of “communities defined by actual shared interests” is a “traditional race-neutral districting principle[.]” *Miller v. Johnson*, 515 U.S. 900, 916 (1995).

Here, the Governor’s decisions regarding communities of interest were, in many cases, drawn from feedback submitted by voters via the Governor’s Public Comment Portal and from testimony received in listening sessions held by the Governor’s Redistricting Advisory Council. Indeed, as of mid-January, the Redistricting Public Comment Portal had received more than 500 submissions of comments, communities of interest, and even full congressional maps. Each of

these submissions was reviewed and contributed to the development of the Governor's Plan. For example, numerous comments submitted to the Public Comment Portal requested that the City of Reading not be divided, in order to preserve an expanding Latino community in the city. In addition, numerous comments similarly requested that Centre County be kept whole. Both of these suggestions were honored in the Governor's Plan.

B. The Governor's Plan Does Not Entrench a Structural Partisan Advantage and Promotes Accountability and Responsiveness to Voters.

As shown by Dr. Duchin's analysis, the Governor's Plan exhibits no partisan skew. This analysis is particularly crucial given the Court's warning, in *League of Women Voters I*, that even maps "minimally comporting with the[] neutral 'floor' criteria" could "nevertheless operate to unfairly dilute the power of a particular group's vote for a congressional representative." 178 A.3d at 817. Indeed, as our Supreme Court has repeatedly acknowledged, one such form of vote dilution is "unfair partisan political advantage[.]" *Id.*; see also *Mellow*, 607 A.2d at 210 (assessing whether the proposed plan maintained a "politically fair balance in the Pennsylvania delegation between Democrats and Republicans").¹²

¹² Similarly, the U.S. Supreme Court has recognized that states can include in their "legitimate considerations ... the competitive balance among political parties." *Harris v. Ariz. Independent Redistricting Comm.*, 578 U.S., 253, 258 (2016).

As described in her Report, Dr. Duchin used best practices from mathematics and statistics to assess whether potential maps, including the Governor’s Plan, exhibited partisan fairness and promoted accountability and responsiveness to voters. Conceptually, numerical measures of partisan fairness “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.” Ex. A, Duchin Report at 13. Dr. Duchin described partisan fairness and accountability and responsiveness to voters in terms of two core principles: first, a political party winning the majority of votes ought, as a general matter, to win a majority of congressional seats (the “Majority-Rule Principle”); and second, elections with close vote margins ought generally to result in a close split in the number of seats won (the “Close-Votes-Close-Seats Principle”). *Id.* at 13.

1. The Overlay Method

Using what is known as an overlay method, Dr. Duchin took the various redistricting plans she was studying and overlaid them with voting patterns from individual past Pennsylvania elections. *Id.* at 14-16. This method allowed her to draw conclusions about whether the respective plans entrench a structural partisan bias at odds with accountability and responsiveness to voters—or, conversely, are faithful to the fundamental premises of representative government.

Importantly, these basic tenets of partisan fairness and representative government by no means entail a commitment to strictly proportional outcomes. *See id.* at 13. Instead, the Majority-Rule and Close-Votes-Close-Seats principles merely reflect the uncontroversial—if not universally held—proposition that a political party that wins a majority of votes should not systematically receive a minority of seats. *Id.* Applying the Majority-Rule and Close-Votes-Close-Seats Principles “inures to no political party’s benefit or detriment. It simply achieves the constitutional goal of fair and equal elections for all of our Commonwealth’s voters.” 178 A.3d at 816.

For obvious reasons, a map that *ignores* accountability and responsiveness to voters, and instead entrenches a systematic partisan skew, is deeply undesirable. First, at its core, it violates the basic tenet of representative republican government: that political preferences shared by a majority of citizens should be represented by a majority of elected legislators. Second, it actively vitiates accountability and responsiveness to voters, effectively predetermining elections regardless of variations in public opinion or political trends. Put simply, changes in the political preferences of voters should be reflected in electoral outcomes, *particularly* in a deeply “purple” state like Pennsylvania, in which the 2020 presidential race was

decided by a margin of 1.2% of the vote, and the 2016 presidential race was decided by a margin of less than 0.3% of the vote.¹³

Here, the overlay method shows that the Governor’s Plan results in a level “partisan playing field,” while the House Map “entrenches a Republican advantage.” Ex. A, Duchin Report at 16. The Governor’s Plan therefore “provides the people of this Commonwealth an equally effective power to select the representative of his or her choice.” *League of Women Voters I*, 178 A.3d at 814. On the other hand, if a district map exhibits a structural partisan skew, so that significant shifts in voter preference—including, in particular, a change in which political party wins a majority of the votes—do not alter electoral outcomes, then elected representatives will have little incentive to respond to the changing needs and desires of the electorate. Such a map contravenes the “mandate[e] that the power of [each] vote in the selection of representatives be equalized to the greatest degree possible with all other Pennsylvania citizens,” *id.* at 817, and fails to honor

¹³ Department of State, 2020 Presidential Election Official Returns, <https://www.electionreturns.pa.gov/General/SummaryResults?ElectionID=83&ElectionType=G&IsActive=0>; Department of State, 2016 Presidential Election Official Returns, <https://www.electionreturns.pa.gov/General/SummaryResults?ElectionID=54&ElectionType=G&IsActive=0>; see also Andrew Seidman, *Pennsylvania is here to stay as a swing state*, PHILA. INQUIRER, Nov. 16, 2020, <https://www.inquirer.com/politics/election/pennsylvania-swing-state-20201116.html>.

the basic promise of the American experiment—that our government shall be one “of the people, by the people, for the people.”¹⁴

2. Ensemble Method

Dr. Duchin also compared the Governor’s Plan and several other maps (including the House Map) with an “ensemble” of 100,000 randomly drawn districting plans, to see how the maps would perform across recent elections. To compare the Governor’s Plan to the ensemble, Dr. Duchin employed four metrics to measure the partisan fairness of a given congressional district map. First, Dr. Duchin quantified each map’s “efficiency gaps,” which is “based on the idea of wasted votes, defined as any winning votes in excess of 50%, or any losing votes at all.” Ex. A, Duchin Report at 17. Second, Dr. Duchin calculated each map’s “Eguia artificial partisan advantage,” which “compares the outcomes under districted plurality elections to the outcomes under ostensibly neutral political subdivisions, such as counties.” *Id.* Third, Dr. Duchin determined each map’s “mean-median score,” which indicates “how much of the vote in a state is needed to capture half of the representation.” *Id.* And fourth, Dr. Duchin computed each map’s “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.” *Id.*

¹⁴ Abraham Lincoln, “The Gettysburg Address” (Nov. 19, 1863).

Dr. Duchin’s analysis confirms that the Governor’s Plan does not create any systematic partisan advantage. To the contrary, when measured using any of the four partisan fairness metrics, the Governor’s Plan creates a level electoral playing field and promotes accountability and responsiveness to voters.

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

Id. Under the Governor’s Plan, instead of entrenching politicians, districts are responsive to Pennsylvania political trends and prevailing voter preference.

Thus, when analyzed using the overlay and ensemble methods, the Plan (1) reflects the Majority Rule Principle, as the political party winning the majority of votes statewide is predicted, as a general matter, to win a majority of congressional seats, (2) adheres to the Close-Votes-Close-Seats Principle, meaning an electoral climate with a roughly 50-50 split in partisan preference should produce a roughly 50-50 representational split, and (3) preserves “swing” districts that can be won by members of either major political party under recent voting patterns. In short, the Governor’s Plan embodies, and fully realizes, the “core principle of our republican form of government[:] ‘that the voters should choose their representatives, not the

other way around.”” *League of Women Voters I*, 178 A.3d at 740-41 (citation omitted).

CONCLUSION

The Governor’s Plan is exactly the sort of redistricting map that the Supreme Court called for in *League of Women Voters I* and *II*. Complying with traditional redistricting criteria, the Plan protects voters’ ability to select the congressional representatives of their choice. Indeed, as shown by Dr. Moon’s rigorous analysis, the Plan not only respects *League of Women Voters I*’s prohibitions on vote dilution and entrenching partisan advantage, but it also promotes the principles of fairness and democratic accountability that *League of Women Voters* extols. In sum, the Plan optimizes all relevant considerations: contiguity, compactness, population equality, minimization of county and municipal splits, preservation of communities of interest, preservation of the cores of pre-existing districts, and—of signal importance—partisan fairness and democratic accountability.

For the foregoing reasons, Intervenor-Respondent Thomas W. Wolf respectfully requests that the Court adopt his Proposed 17-District Congressional Redistricting Plan.

Respectfully submitted,

HANGLEY ARONCHICK SEGAL
PUDLIN & SCHILLER

Dated: January 24, 2022

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CERTIFICATION REGARDING 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.

Dated: January 24, 2022

/s/ Robert A. Wiygul
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EXHIBIT A

Comparison of Congressional Districting Plans in Pennsylvania

Moon Duchin
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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.

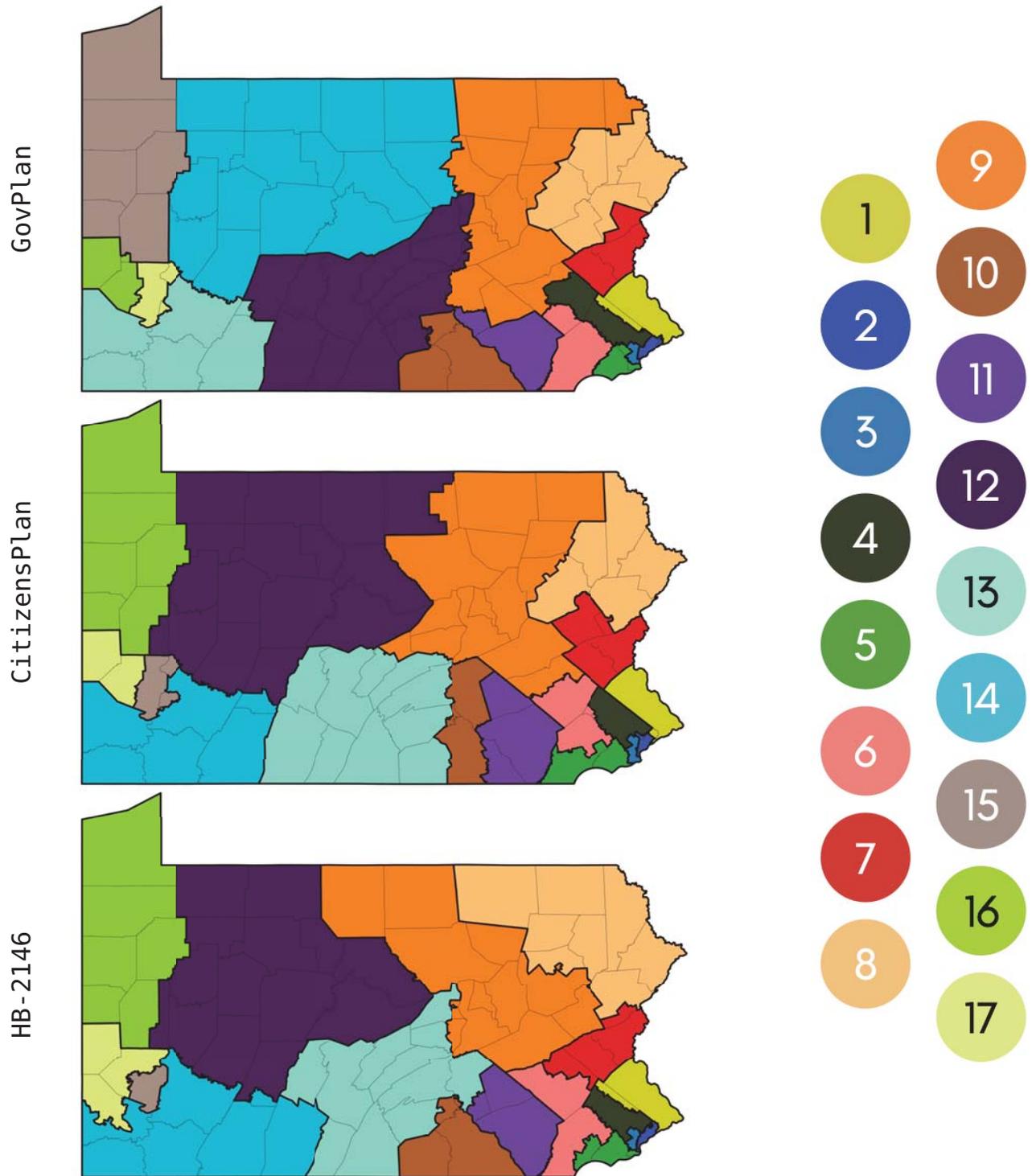


Figure 1: The three plans being compared in this report.

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.

¹The 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

²Philadelphia 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).

³Schwartzberg 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.

⁴The Census Bureau publishes these in its COUSUB file; Pennsylvania 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

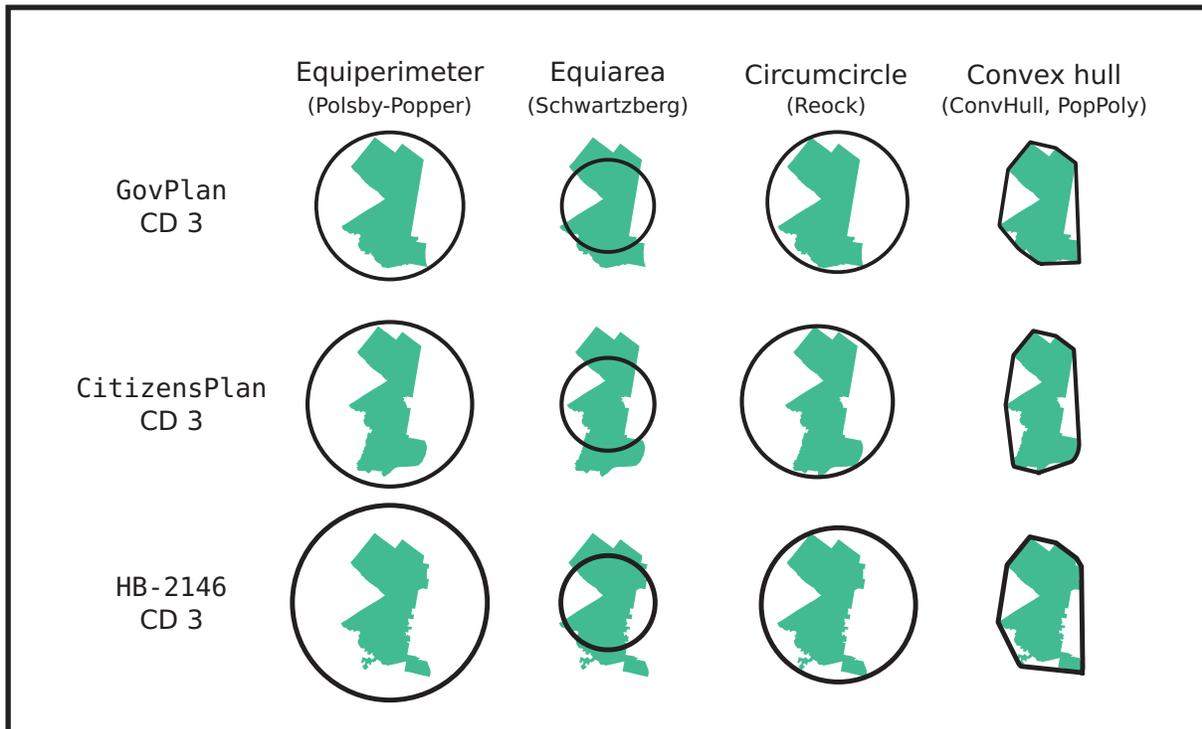
⁵The same one-person deviation is maintained if the dataset shifts to the adjusted LRC1 data referenced above.

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.

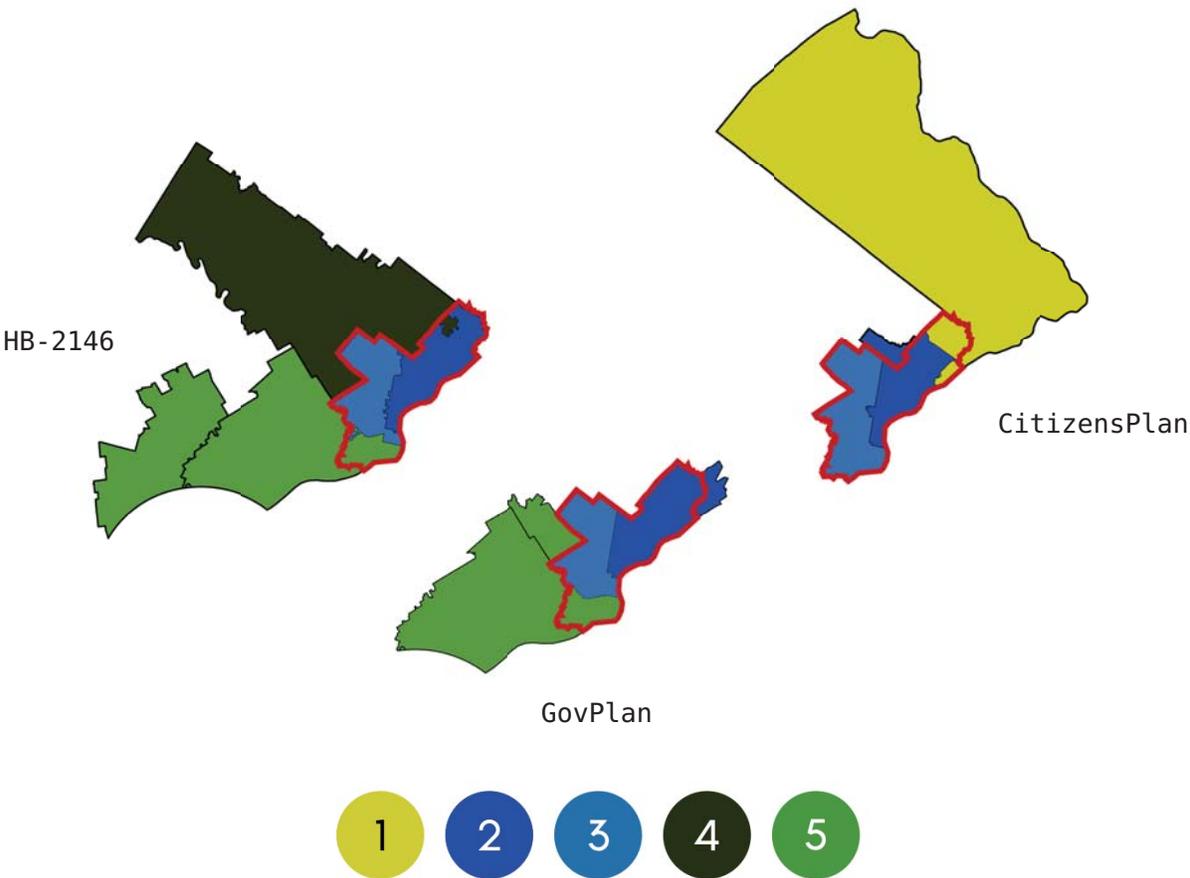
Table 5: Each of the three plans has two districts that pair incumbents and one district with no incumbent.

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	Resenthaler	Joyce	Joyce
14	Thompson	Resenthaler	Resenthaler
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.

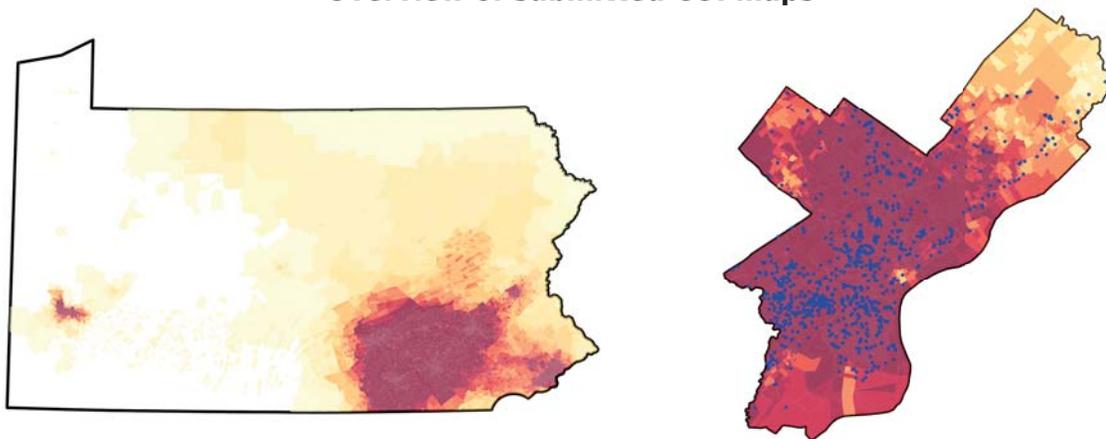
With respect to the 2015 elections, GovPlan has D.Green as a top-two finisher in all three of its Philadelphia districts, with B.Brown essentially tied in CD 3. CitizensPlan has very strong outcomes for both Brown and Green in its CD 3, but districts 1 and 2 do not have either one in the top two finishers. 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.

Overview of submitted COI maps



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.

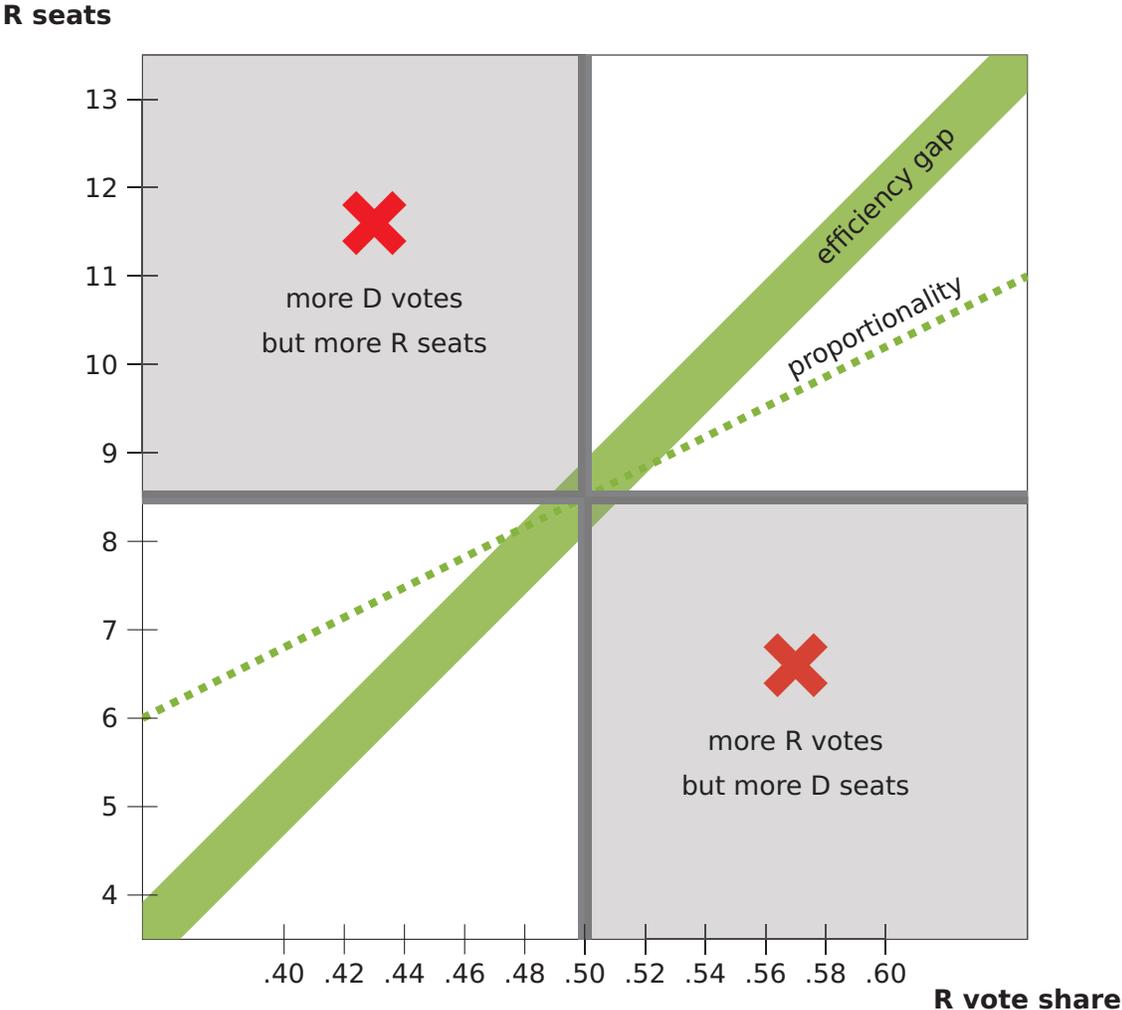
The clear conclusion is that the political geography of Pennsylvania today does not obstruct the selection of a map that treats Democratic and Republican voters fairly and even-handedly.

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.

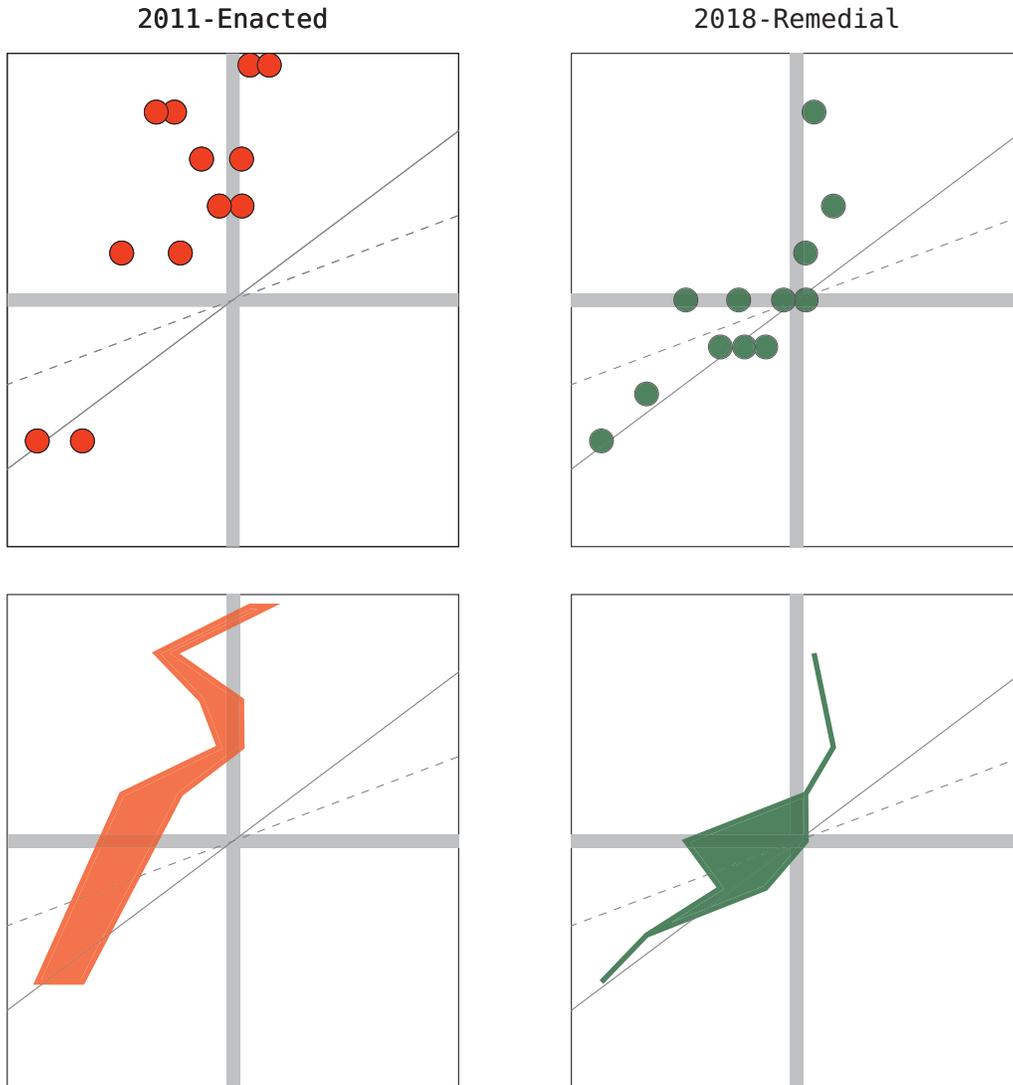
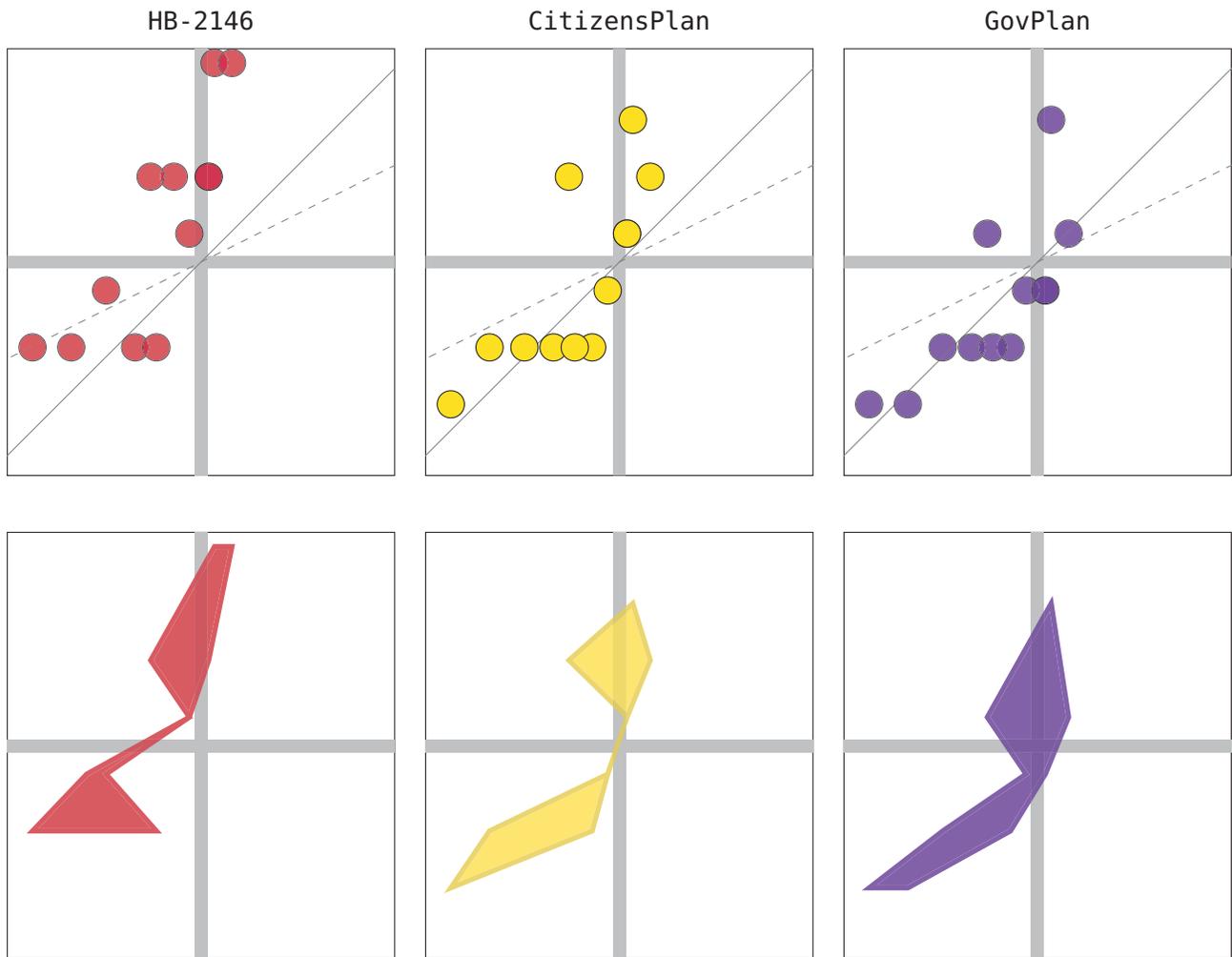


Figure 6: This time, the three new proposed plans are overlaid on the same elections. HB-2146 entrenches a Republican advantage, while CitizensPlan and especially GovPlan are far superior at leveling the partisan playing field.



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 Egua'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.

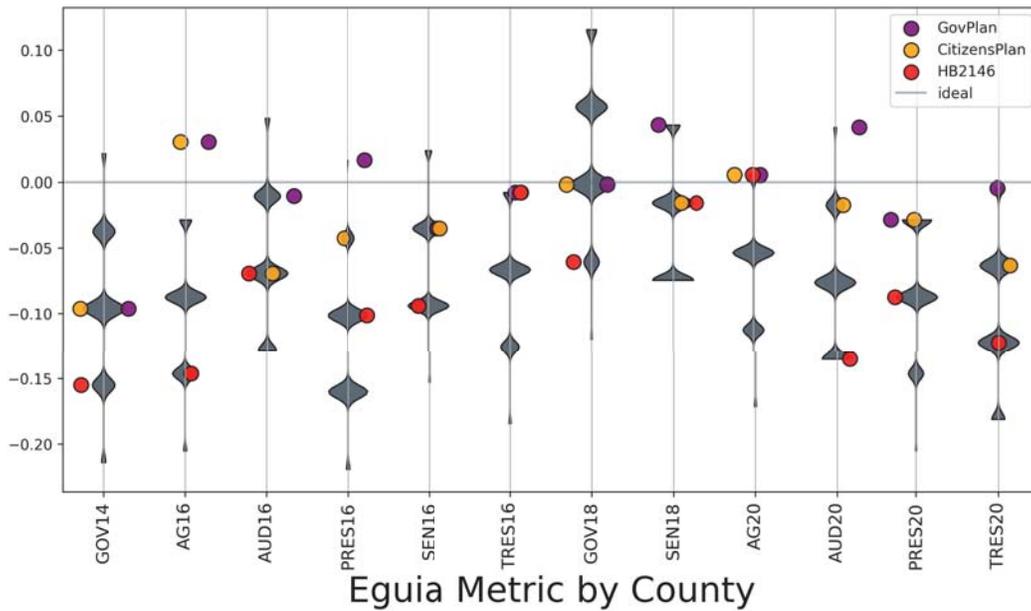
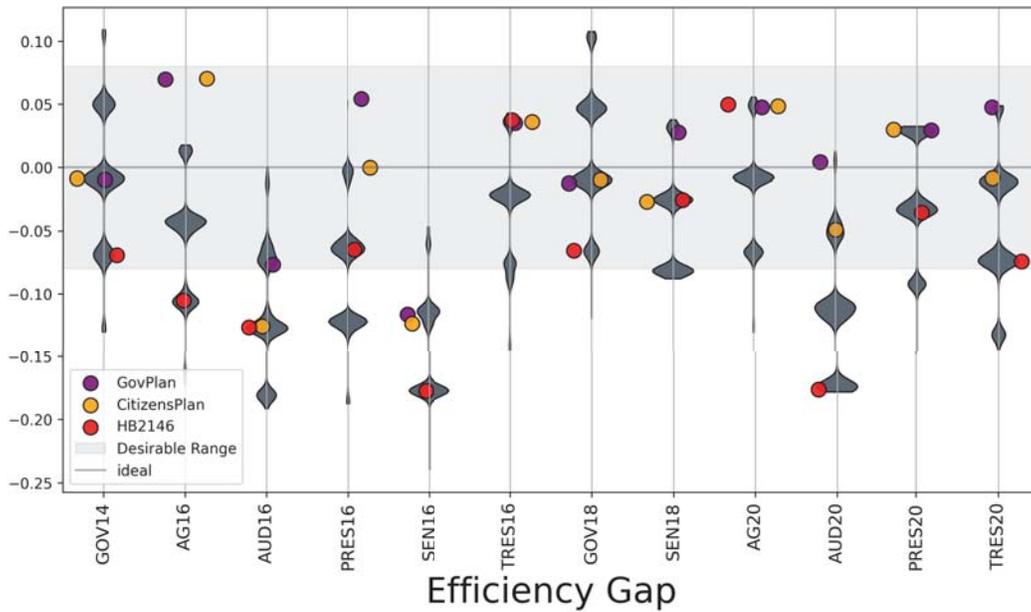
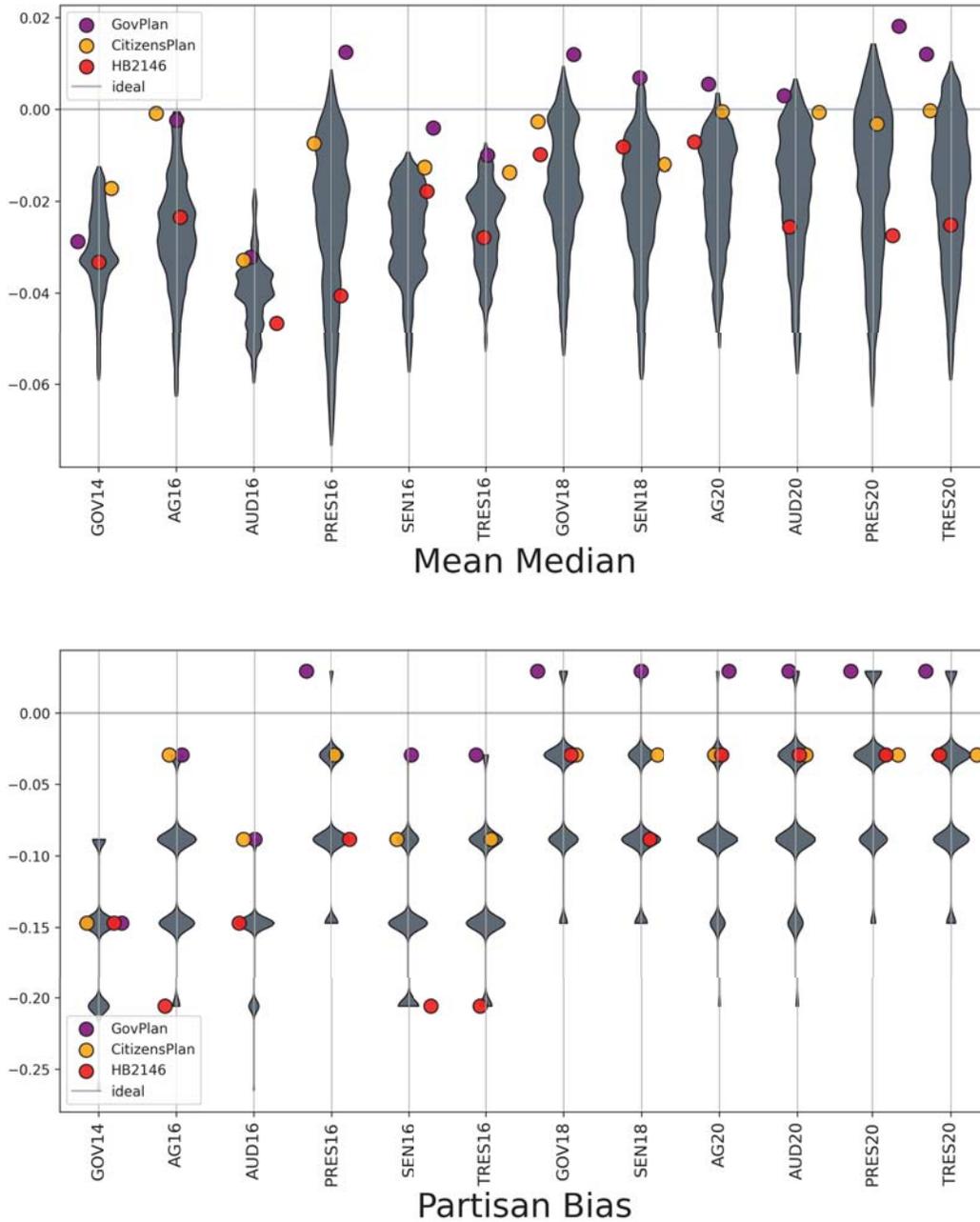


Figure 8: This time, the metrics are from the *partisan symmetry* family, namely the *mean-median score* and the *partisan bias score*. Once again, random plans favor Republicans, while GovPlan and CitizensPlan temper that tendency.



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.

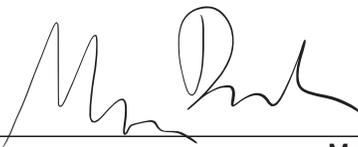
These words ring true in 2022. Indeed, the science of computational redistricting has made great strides even in the last four years, and it is now possible to use algorithmic assistance not only to understand the universe of possibility created by the rules and priorities of redistricting, but to find 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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- [10] Bernard Grofman, *Measures of Bias and Proportionality in Seats-Votes Relationships*. *Political Methodology*, Vol. 9, No. 3 (1983), 295–327.

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

Executed this 24th day of January, 2021.



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Education

University of Chicago Mathematics Advisor: Alex Eskin Dissertation: <i>Geodesics track random walks in Teichmüller space</i>	MS 1999, PhD 2005
Harvard University Mathematics and Women's Studies	BA 1998

Appointments

Tufts University Professor of Mathematics Assistant Professor, Associate Professor <i>Director</i> Program in Science, Technology, & Society (on leave 2018–2019) <i>Principal Investigator</i> MGGG Redistricting Lab <i>Senior Fellow</i> Tisch College of Civic Life	2021— 2011–2021 2015–2021 2017— 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

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2nd Symposium on Foundations of Responsible Computing (FORC 2021), 5:1–5:22. online.

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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.

Geodesics track random walks in Teichmüller space

PhD Dissertation, University of Chicago 2005.

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.

reprinted from Scientific American, November 2018, 48–53.

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 75th Anniversary Meeting of Canadian Mathematical Society, Ottawa, Ontario	June 2021 <i>online (COVID)</i>
BMC/BAMC Public Lecture Joint British Mathematics/Applied Mathematics Colloquium, Glasgow, Scotland	April 2021 <i>online (COVID)</i>
AMS Einstein Public Lecture in Mathematics Southeastern Sectional Meeting of the AMS, Charlottesville, VA	[March 2020] <i>postponed</i>
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	- Université de Neuchâtel	Jun 2016
- Georgetown (CS)	Sept 2020	- Brandeis University	Mar 2016
- Santa Fe Institute	July 2020	- Swarthmore College	Oct 2015
- UC Berkeley	Sept 2018	- Bowling Green	May 2015
- Brandeis-Harvard-MIT-NEU	Mar 2018	- City College of New York	Feb 2015
- Northwestern University	Oct 2017	- Indiana University	Nov 2014
- University of Illinois	Sept 2017	- the Technion	Oct 2014
- University of Utah	Aug 2017	- Wisconsin-Madison	Sept 2014
- Wesleyan	Dec 2016	- Stony Brook	March 2013
- Worcester Polytechnic Inst.	Dec 2016		

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 <i>principal co-authors: Guy-Uriel Charles and Moon Duchin</i> Supreme Court of the United States, in <i>Rucho v. Common Cause</i> - cited in dissent	2019
Committee on Science Policy American Mathematical Society	2020–2023
Program Committee Symposium on Foundations of Responsible Computing	2020–2021
Presenter on Public Mapping, Statistical Modeling National Conference of State Legislatures	2019, 2020
Committee on the Human Rights of Mathematicians American Mathematical Society	2016–2019
Committee on The Future of Voting: Accessible, Reliable, Verifiable Technology National Academies of Science, Engineering, and Medicine	2017–2018

Visiting Positions and Residential Fellowships

Visiting Professor Department of Mathematics Boston College Chestnut Hill, MA	Fall 2021
Fellow Radcliffe Institute for Advanced Study Harvard University Cambridge, MA	2018–19
Member Center of Mathematical Sciences and Applications Harvard University Cambridge, MA	2018–19
Visitor Microsoft Research Lab MSR New England Cambridge, MA	2018–19
Research Member Geometric Group Theory program Mathematical Sciences Research Institute Berkeley, CA	Fall 2016
Research Member Random Walks and Asymptotic Geometry of Groups program Institut Henri Poincaré Paris, France	Spring 2014
Research Member Low-dimensional Topology, Geometry, and Dynamics program Institute for Computational and Experimental Research in Mathematics Providence, RI	Fall 2013
Research Member Geometric and Analytic Aspects of Group Theory program Institut Mittag-Leffler Stockholm, Sweden	May 2012
Research Member Quantitative Geometry program Mathematical Sciences Research Institute Berkeley, CA	Fall 2011
Postdoctoral Fellow Teichmüller "project blanc" Agence Nationale de la Recherche (Collège de France) Paris, France	Spring 2009