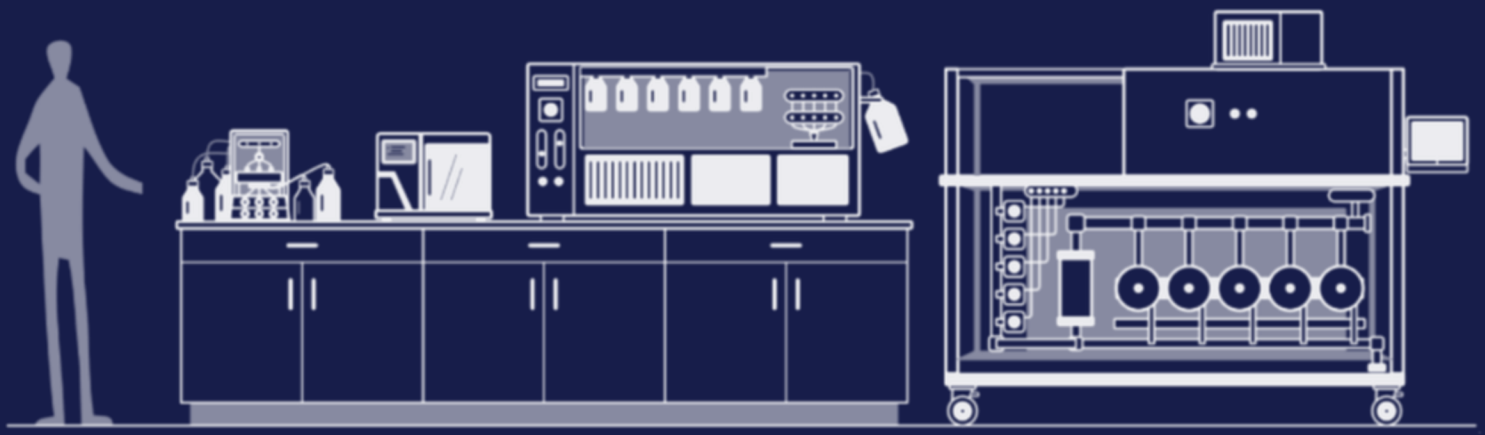
The Benchtop Nucleic Acid Synthesis Device Landscape

Preliminary Findings

Ivet A. Yordanova[1], Kirsten Engel[2], Mayra Ameneiros[1], Gary Abel[3,4], Tessa Alexanian[1*]

[1] International Biosecurity and Biosafety Initiative for Science (IBBIS), Geneva, Switzerland
[2] SecureDNA Foundation, Geneva, Switzerland
[3] Fourth Eon Biosecurity Institute, Berkeley, CA, United States
[4] The Johns Hopkins Center for Health Security, Baltimore, MD, United States



November 13, 2026 | Version 1.0

The Benchtop Nucleic Acid Synthesis Device Landscape

Preliminary Findings

Ivet A. Yordanova [1], Kirsten Engel [2], Mayra Ameneiros [1], Gary Abel [3,4], Tessa Alexanian [1*]

[1] *International Biosecurity and Biosafety Initiative for Science (IBBIS), Geneva, Switzerland*
[2] *SecureDNA Foundation, Geneva, Switzerland*
[3] *Fourth Eon Biosecurity Institute, Berkeley, CA, United States*
[4] *The Johns Hopkins Center for Health Security, Baltimore, MD, United States*

[*] *Corresponding author: hello@tessa.fyi*

Background

Benchtop nucleic acid synthesis devices provide rapid, decentralized access to synthetic DNA and are used by life sciences research labs, academic core facilities, pharmaceutical companies, diagnostic laboratories, and small-scale mail-order synthesis companies[1]. Given the dual-use potential of synthetic DNA, recent policy proposals have called for extending sequence and customer screening obligations from centralized commercial synthesis providers to manufacturers of benchtop synthesis devices. However, the challenges of adapting screening to benchtop devices have yet to be adequately addressed[2].

These preliminary findings summarize our survey of the benchtop nucleic acid synthesis landscape, examining all benchtop devices that are currently available, under development, or discontinued. Our forthcoming report will provide more detail on benchtop device types and capabilities, map the global distribution of manufacturers, assess regulatory and policy definitions of benchtop devices, and compare technical safeguards. We expect this comprehensive assessment of the benchtop nucleic acid synthesis landscape will provide valuable insights to guide the development of effective policy frameworks and technical safeguards, supporting the responsible adoption of these technologies while addressing emerging biosecurity risks.

Current landscape of benchtop synthesis devices

Commercially available nucleic acid synthesis devices come in a range of sizes, from small to large benchtop instruments and floor-standing systems (Fig. 1A). While most benchtop devices employ either chemical phosphoramidite-based synthesis or enzymatic synthesis, a variety of other formats exist (Fig. 1B). Phosphoramidite-based systems include conventional column- or well-based formats as well as array-based approaches, in which synthesis sites may be addressed using electrochemical control, droplet deposition, photolithographic deprotection, or other localized reactions. Enzymatic synthesis represents an alternative approach based on nucleotide incorporation by enzymes such as engineered terminal deoxynucleotidyl transferase[3-6]. Analysis of available device specifications and synthesis capacities shows that array-based devices have the highest synthesis throughput capabilities, evidenced by their ability to synthesize as many as 1.5 billion unique nucleotides across up to 4,350,000 sites per run (Fig. 1C, D).

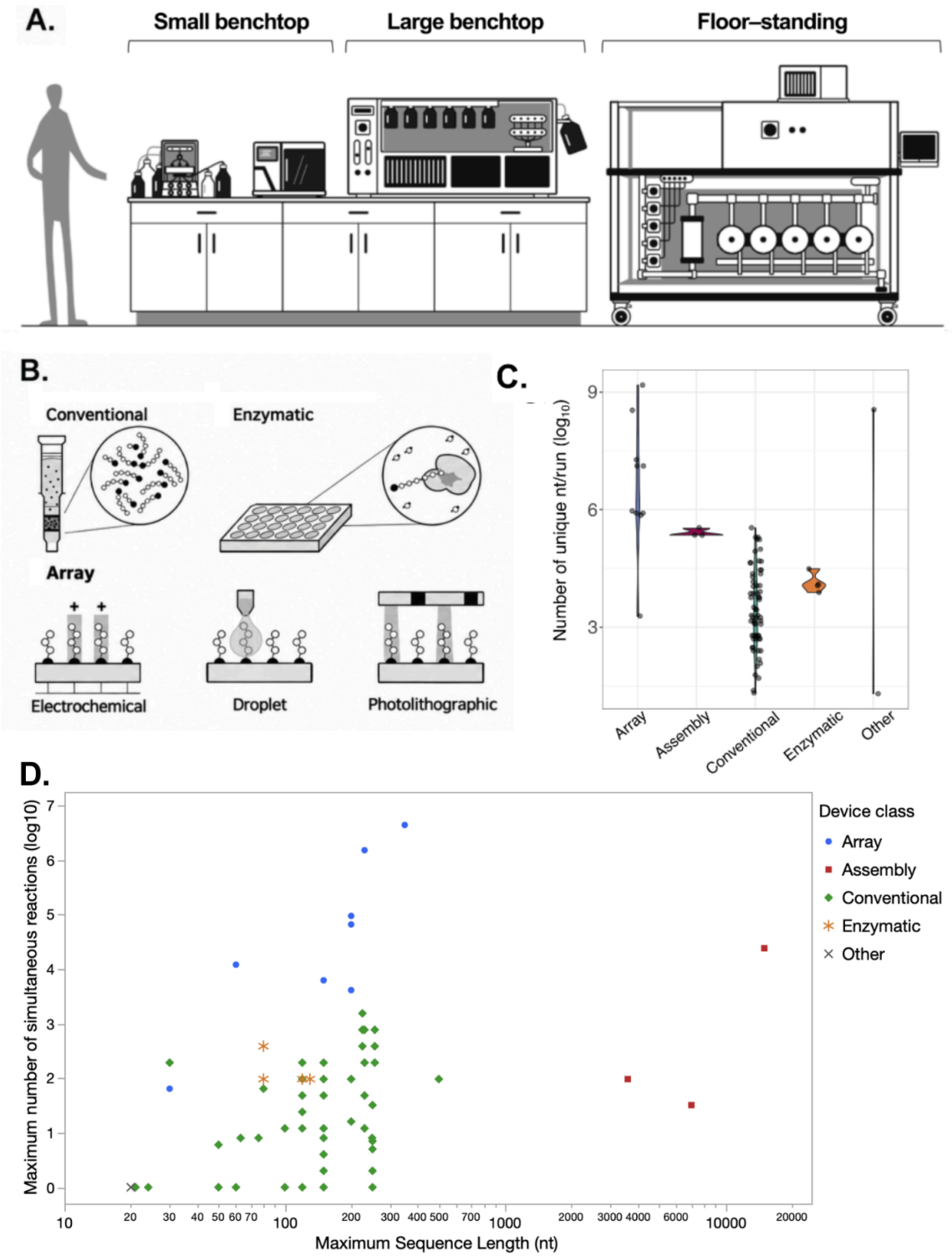


Figure 1. Benchtop synthesis devices and capabilities. (A) Simplified illustration of benchtop formats, showing the range from small research-scale devices to floor-standing production-scale synthesizers. (B) Simplified illustration of the main synthesis formats for current devices: conventional column or well-based phosphoramidite synthesis, enzymatic synthesis, or array-based chemistry, which may be addressed using several different strategies. (C) Violin plot of synthesis capacity of benchtop devices, grouped by device class and expressed as the number of unique nucleotides synthesized per run (log_{10} scale), which is calculated as the throughput multiplied by the maximum sequence length in nucleotides. (D) Scatter plot of the maximum throughput per run multiplied by the maximum sequence length. Each point in C and D represents one device model (n = 83). Devices for which capacity could not be derived from publicly available specifications are not shown (n = 197).

Among the benchtop synthesis devices identified in this survey, device manufacturers were headquartered across eleven countries: Austria, Canada, China, Denmark, France, Germany, Japan, Russia, Sweden, the United Kingdom, and the United States (USA). Among these, China (31.8%), the USA (25%), and Japan (11.8%) contribute the highest numbers of benchtop device models, while the total share across the EU is 16.8% (Fig. 2A).

The first benchtop synthesis devices released on the market in the 1980s relied predominantly on conventional phosphoramidite chemistry for DNA synthesis. In the decade from 2006 to 2015, an average of 3.7 new benchtop device models emerged annually. The release rate has since increased significantly, with an average of 9.3 new models per year in the following decade from 2016 to 2025 (Fig. 2B). Though the exact release date was not publicly available for every model, our comprehensive analysis of publicly available data found that an estimated total of 280 device models have been introduced since the early 1980s, 102 of which have since been discontinued from production.

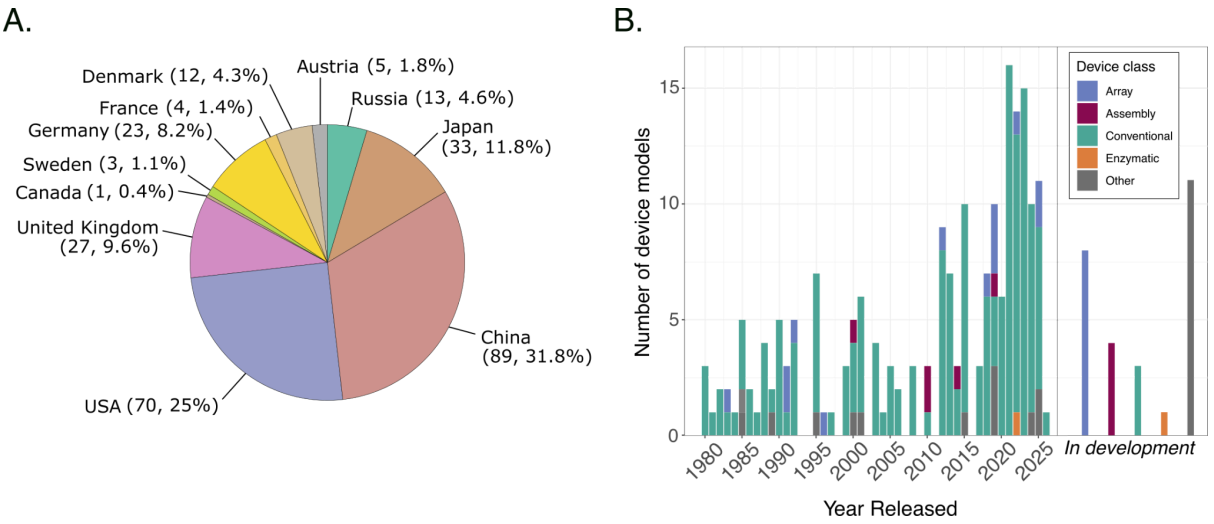


Figure 2. The global benchtop nucleic acid synthesis device landscape. (A) Pie chart of the country where the manufacturer is headquartered for benchtop devices included in the report (n = 280). (B) Stacked bar chart of the number of benchtop device models released per year, coloured by device class (n = 166). Devices still in development (n = 27) are shown on the right side of the bar chart. "Other" denotes devices using synthesis chemistry other than phosphoramidite and enzymatic, or whose synthesis method has not been disclosed. Devices with no publicly available release date (n = 87) are not shown.

Safeguarding benchtop synthesis devices

Currently, there are no international regulatory requirements or consensus best practices for benchtop device biosecurity[2]. The November 2026 US National Policy for Nucleic Acid Synthesis Screening establishes obligations for device manufacturers and calls for the creation of technical standards for synthesis screening on benchtop devices, including the form, issuance, cryptographic verification, physical security, and validity of authorization issued by verified screening tools to individual benchtop devices[7].

Safeguards for benchtop devices can be implemented through a layered approach encompassing know-your-customer (KYC) screening, operator-device interactions, software and hardware controls, and record-keeping mechanisms (Fig. 3).

- **KYC screening**: In addition to KYC checks at the point of device purchase or transfer, proprietary consumables (reagents, kits, cartridges) create additional opportunities for ongoing customer or site verification, including for devices sold to third parties.
- **Operator-device interactions**: Device use can be secured by ensuring users are uniquely authenticated through tiered licensing and multi-factor authentication, pairing licenses for individual access levels with cryptographic credentials or electronic signatures. KYC may be used to set a default tier on each device.
- **Software controls**: Synthesis requests can then be authorized using networked authorization or "phone-home" screening (requiring careful secure handling of proprietary sequences)[8] or offline screening (requiring careful secure handling of screening databases and software updates).
- **Hardware controls**: Software-only screening and authorization can be bypassed unless devices implement hardware safeguards. For example, secure boot backed by a hardware root of trust can ensure that firmware and low-level controllers for electronics, fluidics, and thermal modules execute only signed jobs, preventing untrusted actuation of synthesis hardware. Additionally, tamper-proofing mechanisms could be used to detect unauthorized physical access to device components, triggering lockout or requiring inspection to resume operation.
- **Record-keeping**: At either a hardware or software level, devices can implement an audit log to enable attribution of sequences synthesized on a device[9] and automated reporting to ensure that attempts to tamper with equipment to avoid screening are flagged.

Prioritizing among these safeguards will require careful consideration of the advantages, limitations, and costs of different approaches.

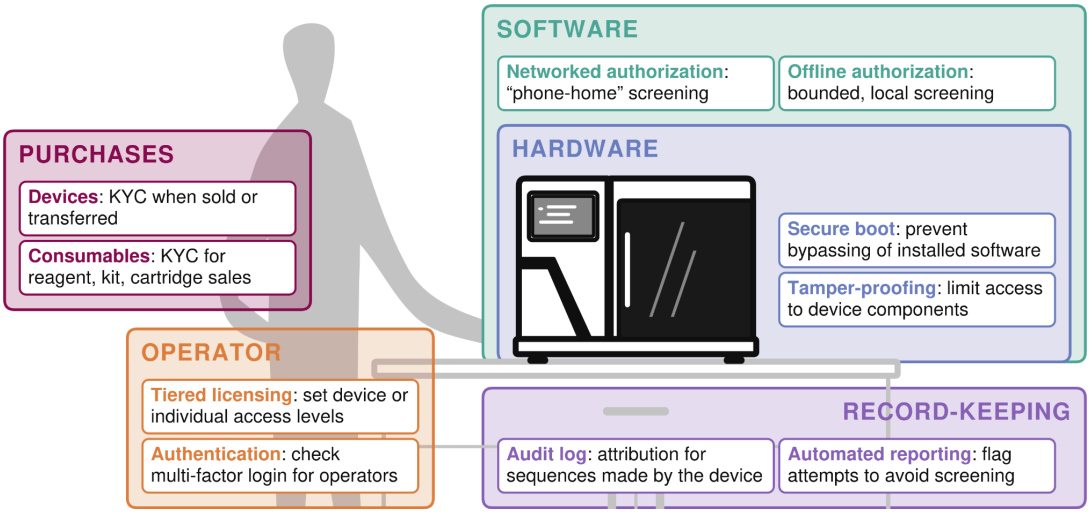


Figure 3. Graphical summary of proposed on-device safeguards for benchtop synthesis devices. Safeguards could be layered across device reagents, purchasers and end-users (customers), software, and device hardware.

Conclusion

Benchtop synthesis devices are proliferating across a growing set of manufacturers, jurisdictions, and synthesis methods, and their throughput now approaches scales previously only available from mail-order synthesis providers. The full report and associated dataset will give manufacturers, screening tool providers, policymakers, and biosecurity advocates a shared understanding of the benchtop synthesis landscape, helping to inform the development of effective technical safeguards and policy frameworks.

Disclaimers

The data for this publication was obtained exclusively from publicly available sources at the time of the research. No non-public, confidential, proprietary, or otherwise restricted information was relied upon for this work. This research was not undertaken in partnership or collaboration with any manufacturer identified or referenced herein. The inclusion of or reference to any company, product, or service does not imply that such company participated in or endorsed this publication, nor does it imply endorsement of any company, product, or service by the authors or their institutions.

The illustrations in Figures 1 and 3 were created using Claude-Opus-5 (Anthropic) based on data and reference sketches provided by the authors. The raw data provided in Fig. 1 and Fig. 2 were analyzed and visualized in RStudio. All the data analysis scripts will be made available by the authors on a public-access GitHub repository when the full report is published.

Request the data

The complete benchtop device dataset is available upon request for legitimate use. To request access to the data informing this study, please email dataaccess@ibbis.bio. You will receive an application form, and your request will be reviewed through a managed access process administered by IBBIS.

References

1. OligoMaker ApS. Customer cases. *OligoMaker* https://oligomaker.com/customer-cases/ (2024).
2. Langenkamp, M. Securing benchtop DNA synthesizers. *Institute for Progress* https://ifp.org/securing-benchtop-dna-synthesizers (2024).
3. Roy, S. & Caruthers, M. Synthesis of DNA/RNA and their analogs via phosphoramidite and H-phosphonate chemistries. *Molecules* 18, 14268–14284 (2013). https://doi.org/10.3390/molecules181114268
4. Forget, S. M. *et al.* Evolving a terminal deoxynucleotidyl transferase for commercial enzymatic DNA synthesis. *Nucleic Acids Res.* 53, gkaf115 (2025). https://doi.org/10.1093/nar/gkaf115
5. Egeland, R. D. & Southern, E. M. Electrochemically directed synthesis of oligonucleotides for DNA microarray fabrication. *Nucleic Acids Res.* 33, e125 (2005). https://doi.org/10.1093/nar/gni117
6. Holden, M. T. *et al.* Photolithographic synthesis of high-density DNA and RNA arrays on flexible, transparent, and easily subdivided plastic substrates. *Anal. Chem.* 87, 11420–11428 (2015). https://doi.org/10.1021/acs.analchem.5b02893
7. White House. "National Policy for Nucleic Acid Synthesis Screening." Memorandum NSTM-6, November 5, 2026. https://www.whitehouse.gov/wp-content/uploads/2026/11/NSTM-6-NASS-Policy.pdf.
8. Carter, S. R., Yassif, J. M., & Isaac, C. R. *Benchtop DNA Synthesis Devices: Capabilities, Biosecurity Implications, and Governance*. Nuclear Threat Initiative. https://www.nti.org/analysis/articles/benchtop-dna-synthesis-devices-capabilities-biosecurity-implications-and-governance/ (2023).
9. Baker, D. & Church, G. Protein design meets biosecurity. Science 383, 349 (2024). https://doi.org/10.1126/science.ado1671