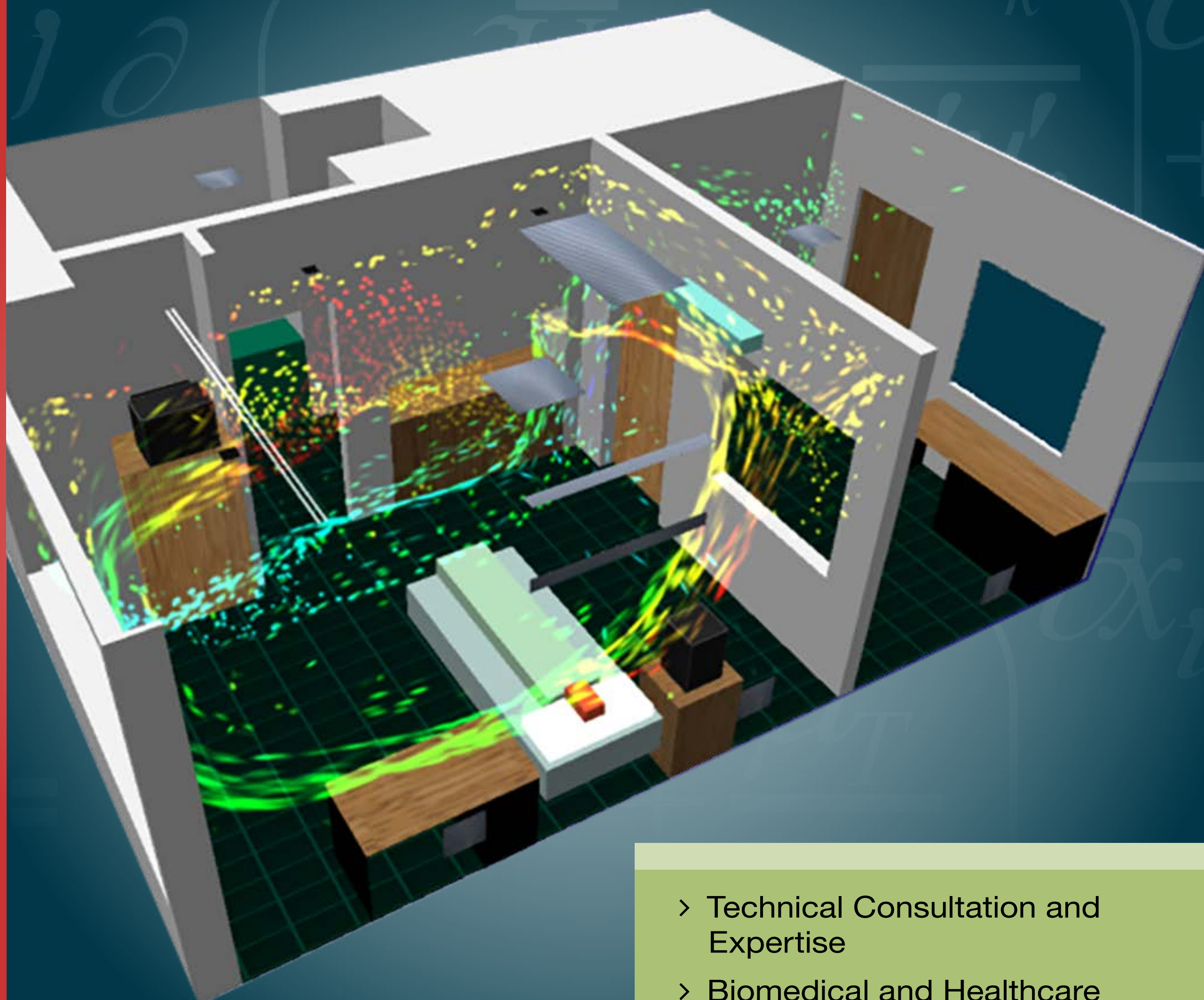
Division of Technical Resources

Leading the Way in Bioenvironmental Studies, Facility Design and Energy Management



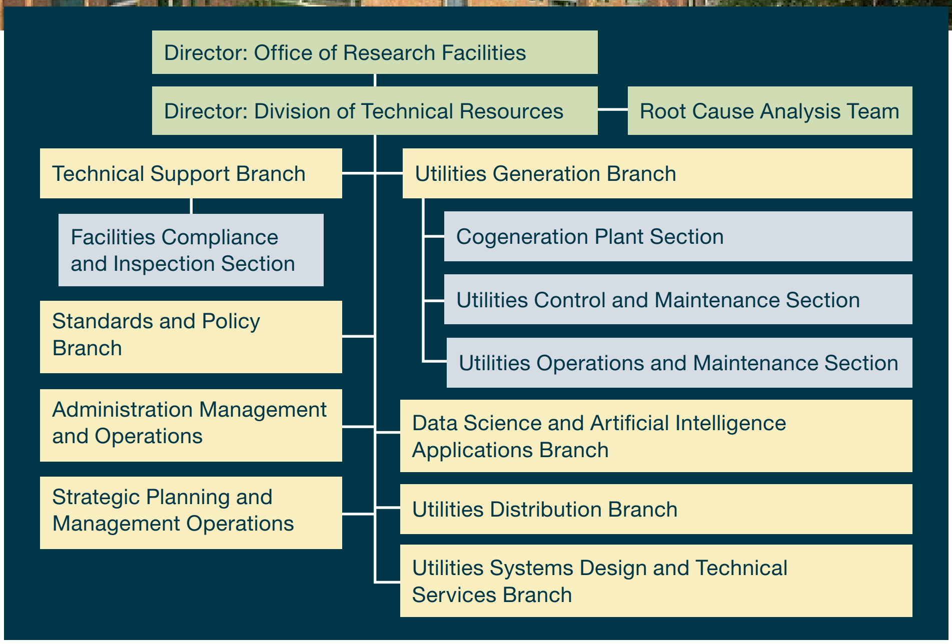
- Technical Consultation and Expertise
- Biomedical and Healthcare Facility Research
- Standards and Policy
- Facility Design Review
- Cup Operations and Maintenance
- Technical Training

National Institutes of Health
Turning Discovery Into Health

Division of Technical Resources
Office of Research Facilities

The formulae $\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_i U_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ $\frac{\partial \rho U_i k}{\partial x_i}=\frac{\partial}{\partial x_i}\left(\left(\mu+\frac{\mu_T}{\sigma_k}\right)\frac{\partial k}{\partial x_i}\right)+P+G-\rho\varepsilon$ *for building* $\frac{\partial \rho U_i \varepsilon}{\partial x_i}=\frac{\partial}{\partial x_i}\left(\left(\mu+\frac{\mu_T}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_i}\right)+(C_1-C_{1RNG})\frac{\varepsilon}{k}(P+C_3G)-C_2\rho\frac{\varepsilon^2}{k}$ $\frac{\partial}{\partial x_i}(\rho \bar{U}_i \bar{H})=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial \bar{T}}{\partial x_i}-\rho\overline{u_i' h'}\right)$ $-\rho\overline{u_i' u_j'}=\mu_T\left(\frac{\partial \bar{U}_i}{\partial x_j}+\frac{\partial \bar{U}_j}{\partial x_i}\right)-\frac{2}{3}\rho k\delta$ *state of the art* $\frac{\partial}{\partial x_j}(\rho \bar{U}_i \bar{U}_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \bar{U}_i}{\partial x_j}-\rho\overline{u_i' u_j'}\right)+g_i(\rho-\rho_0)$ $\frac{\partial \rho U_i \varepsilon}{\partial x_i}=\frac{\partial}{\partial x_i}\left(\left(\mu+\frac{\mu_T}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_i}\right)+C_1\frac{\varepsilon}{k}(P+C_3G)-C_2\rho\frac{\varepsilon^2}{k}$ *biomedical research facilities.*

Providing Innovative and State-of-the-Art Biomedical Facilities and Supporting Infrastructure



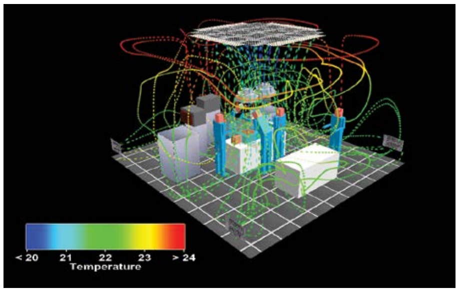
The National Institutes of Health

NIH The NIH mission is to seek fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to enhance health, lengthen life, and reduce illness and disability. The NIH campus has over 75 buildings and a 240-bed hospital on over 300 acres in Bethesda, MD. NIH is the premier biomedical research center in the world.

Division of Technical Resources

DTR The DTR mission is to deliver safe, efficient, cost-effective facilities that support biomedical and clinical research and patient safety.

- Provides technical engineering and bioenvironmental expertise and training for the design and construction of state-of-the-art biomedical, animal, and patient healthcare research facilities, high biocontainment laboratories, aseptic production facilities (APFs), and data centers.
- Conducts scientific bioenvironmental research to resolve technical issues of an unusual scope and difficulty in order to advance emerging scientific technologies used in the design of federal biomedical research facilities. The results of these studies have often been adopted as national and international standards for biomedical laboratories and healthcare facilities.
- Manages and operates the Bethesda Campus Central Utility Plant (CUP), the Cogeneration (COGEN) Plant, and the NIH Utility Distribution System (except electrical distribution) in accordance with State of Maryland environmental standards to ensure that utilities are delivered safely and efficiently.
- Leads advanced studies using empirical and numerical analysis (e.g., computational analysis and mathematical models) to improve biomedical research and healthcare facilities.
- Develops energy forecasting models to reduce energy consumption while improving indoor air quality in biomedical laboratories and animal research and healthcare facilities.
- Leads root cause analysis and implements corrective actions.
- Employs numerical modeling and trend analysis strategies to manage the purchase of natural gas for the NIH COGEN Plant using an Artificial Neural Network (ANN) in conjunction with Holt-Winter triple exponential smoothing that accounts for seasonal and trend changes.



- Authors the NIH Design Requirements Manual (DRM). The DRM is the most comprehensive manual of its kind and is used both nationally and internationally. It has been translated into numerous foreign languages. The DRM is based on best practices and state-of-the-art bioenvironmental research conducted at the NIH. It establishes policy, design requirements, standards, and technical criteria for use in planning, programming, and designing NIH-owned, leased, operated, and funded complex Biosafety Level (BSL) 2-3 biomedical, animal, and healthcare research facilities, insectaries, specialty equipment laboratories, APFs, and data centers. https://www.orf.od.nih.gov/PoliciesAndGuidelines/Pages/DesignRequirementsManual2016.aspx

DTR is one of eight Divisions in the Office of Research Facilities. DTR has eight branches and five sections and groups:

- Technical Support Branch (TSB)
- Facilities Compliance and Inspection Section (FCIS)

Protecting Research and Patient Care Through Facility Design

- Standards and Policy Branch (SPB)
- Strategic Planning and Management Operations (SPMO)
- Administrative Management and Operations (AMO)
- Root Cause Analysis Group (RCA)
- Utilities Generation Branch (UGB)
- COGEN Plant Section
- Utilities Controls and Maintenance Section (UCMS)
- Utilities Operations and Maintenance Section (UOMS)
- Data Science and Artificial Intelligence Branch (DSAIB)
- Utilities Distribution Branch (UDB)
- Utilities Systems Design and Technical Services Branch (USDTSB)

Technical Support Branch

TSB

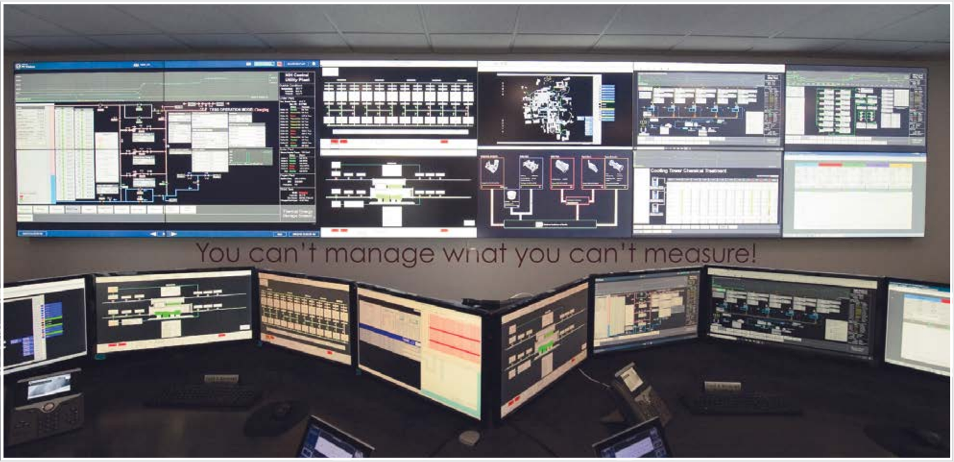
- Ensures that design and construction projects conform to applicable regulations, codes, standards, policies, and guidelines by providing expert technical consultation and analysis, comprehensive design reviews, quality assurance (QA), and oversight for design and construction documents for NIH intramural and extramural facilities such as complex BSL 2-3 biomedical, animal, and healthcare research facilities, specialty equipment laboratories, APFs, and data centers.
- Provides consultive engineering and architectural services to ORF divisions and project design and management teams.
- Identifies Lessons Learned (LL) from design and construction projects and applies the results of these studies and LL to the design of NIH facilities through updates to the NIH DRM.
- Conducts technical research on innovative and novel engineering technologies and methodologies.
- Oversees and provides quality control for the commissioning and certification of new and renovated high biocontainment laboratories.

Facilities Compliance and Inspection Section

FCIS

- Provides Quality Assurance oversight of the planning, design, construction, commissioning, validation, operations, and maintenance of the NIH Aseptic Processing Facility (APF) portfolio (e.g., cleanroom facilities

used to support the production of biologics, pharmaceuticals, and radiopharmaceuticals for human use, typically certified as Current Good Manufacturing Process, or cGMP, facilities).
- Ensures APFs are maintained in compliance with the current regulatory environment, which is highly subject to change.
- Works closely with DFOM to continually monitor APF critical environmental parameters, investigating and resolving the root cause of deviations and implementing continual improvements.
- Produces daily performance reports for every facility in the portfolio.
- Develops and maintains dashboards to display historical and near real-time performance data and other facility information.
- Collaborates with other DTR organizational units to develop purpose-built software tools for statistical analysis, data visualization, and advanced simulator modeling for performance testing, analytics, and modification testing.
- Manages a change-management board for APF facilities which ensures careful consideration is given to all proposed workplans and facility-related changes (i.e., changes to setpoints, targets, alarm ranges, etc.) to ensure the facilities remain operational within specifications and ready to support the critical functions that rely on them.
- Supports Office of Regulatory Support and Compliance (ORSC) and other APF User QA groups on facility issues.
- Develops and maintains APF facility Standard Operating Procedures



(SOPs) for training, documentation, facility management, operation and maintenance (O&M), and reviews and approves SOPs authored by DFOM.

› Operates the Critical Facility Monitoring Center (CFMC), a multipurpose facility for monitoring, Root Cause Analysis (RCA), System Deviation (SD) investigation, support of commissioning, qualification, and validation (CQV) activities, troubleshooting, and other similar functions.

Standards and Policy Branch

SPB › Develops, maintains, and regularly updates the NIH DRM. The DRM is available at: **https://orf.od.nih.gov/technicalresources/pages/designrequirementsmanual2016.aspx**

› Publishes monthly DTR "News to Use" articles that summarize salient features of the DRM for global readers, and NIH "Technical Bulletins" that review design and construction issues relevant to NIH design professionals and operations and maintenance (O&M) staff. The articles are available at: **https://orf.od.nih.gov/TechnicalResources/Pages/DRM_News_to_Use.aspx** and **https://www.orf.od.nih.gov/PoliciesAndGuidelines/Pages/DTR_Technical_Bulletin.aspx**

› Manages the NIH intramural and grant construction project document design review and intake system.

ACCREDITED IACET PROVIDER › Develops, sponsors, and administers courses in new technologies, best practices, and lessons learned in the design and construction of large, complex biomedical research facilities. The DTR Training Program is accredited by the International Association for Continuing Education and Training (IACET) and awards continuing education unit (CEU) credits.

› Manages the ORF Technical Library of codes, standards, and technical publications.

Administrative Management and Operations

AMO › Oversees and facilitates administrative services, conference and travel management, procurement, and property management.

› Fosters a committed, high-performing workforce to meet the DTR mission by providing the tools, services, and training to assist supervisors and managers in selecting and retaining qualified staff and addressing organizational and personnel issues.

› Ensures effective recognition, retention, and engagement strategies. Works to empower DTR leaders with the knowledge and skills to manage a federal workforce, develop staff to enhance performance, and prepare the next generation of leaders.

Strategic Planning and Management Operations

SPMO › Provides oversight and management of DTR's overall vision, goals, objectives, direction, and resources from planning to execution.

› Performs continuous monitoring and evaluation of DTR activities, priorities, and budget to ensure greater operational efficiency and transform processes where necessary.

› Supports and manages the DTR vision and makes decisions that will keep DTR on the path to success for years to come.

› Provides continuous oversight of the DTR budget and programs to ensure accountability, reliability, efficiency, and cost effectiveness.

Root Cause Analysis

RCA › Identifies and addresses the root cause(s) of adverse events and develops corrective actions.

› Performs RCA to prevent and mitigate failures; optimize asset and process reliability; and reduce costs and stress.

› Systematically identifies latent and apparent breakdowns in processes and systems that contributed to the event and how to prevent future events.

› Forecasts maintenance activities.

› Conducts maintenance effectiveness reviews.

› Investigates what happened, why it happened, how it happened, and what changes need to be made to prevent future occurrences.

› Performs internal and cross-team training, including lessons learned from DTR/DFOM engineers and building automation system code instruction.

NIH Central Utility Plant

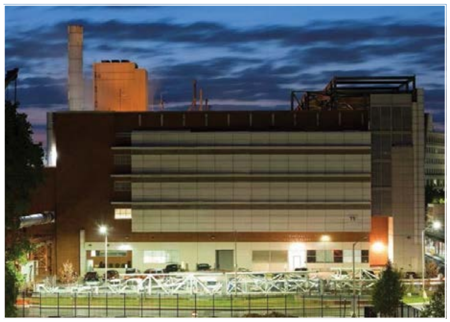
CUP The NIH CUP is one of the largest and most technically advanced utility plants in the world. The NIH Cogeneration (COGEN) Plant is a unique NIH design that makes it one of the cleanest cogeneration plants in the country. The NIH CUP is the heart of the NIH campus. The CUP provides highly reliable and efficient utilities (e.g., heating, cooling, humidity, electrical, mechanical and plumbing) to critical research and clinical facilities. CUP engineers use Big Data, Machine Learning (ML) and Artificial Intelligence (AI) algorithms to detect patterns and predict likely outcomes or actions based on those patterns and relationships. The algorithms utilize over 35 million automated points from approximately 5,000 continuously running analyses and over 1,000,0000 calculations per day.

The CUP branches work together to provide 24/7/365 utility services to the NIH campus efficiently, optimally, cost-effectively, and in accordance with State of Maryland environmental standards, while decreasing environmental emissions and increasing operational up-time.

The CUP facility is comprised of the following interconnected systems and features (*refer to the DTR CUP brochure for statistics and detailed CUP information*):

Powering Biomedical Research – Central Utility Plant (CUP) Branches

› **The Boiler Plant** has five boilers and provides the entire campus with steam and compressed air, which is used for heating, humidity control, and critical processes such as sterilization, cage washing, and pneumatic controls. Each year, the plant burns about 3.1 – 3.7 billion standard cubic feet of natural gas to generate about 2.5 billion pounds of steam for the NIH Bethesda Campus buildings and facilities. It is capable of producing 980,000 pounds per hour (PPH) of 373°F steam at 165 PSI at full load capacity. The Boiler Plant utilizes both natural gas and/or diesel fuel for steam production.

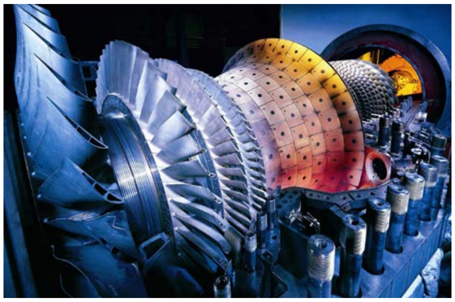


› **The Chiller Plant** has ten 5,000-ton and two 6,200-ton centrifugal refrigeration "chillers." These efficiently transfer heat from the campus buildings via refrigerant gas and condensing water between the evaporator and heat exchangers. The condensers reject heat to the atmosphere via evaporative cooling towers. The chillers generate a maximum of 62,400 tons of chilled water at 126,000 gallons per minute. They consume about 165,000 megawatt hours (MWh) of electricity annually, roughly equivalent to the electrical energy required to air condition 100,000 households for a year. In addition to the refrigeration cooling, the free cooling system produces 3,000-9,000 additional tons of chilled water during the winter by using cooling towers when the ambient temperature is low..

› **The Cogeneration Plant** enables NIH to meet National Ambient Air Quality Standards more effectively and economically than traditional boilers. Cogeneration saves the NIH an estimated average of $15 million per year in steam and electricity costs. The energy savings is equivalent to the energy used by about 5,000 households per year. The NIH Cogeneration Plant has been in operation since July 2004. The Cogeneration Plant operates at base load to generate 23 megawatts of electricity and 105,000 pounds per hour of steam, with the capability to generate 180,000 pounds per hour of steam using auxiliary duct firing. Cogeneration base load production represents approximately 40% of the current average campus electricity and steam load.

› **The Industrial Water Storage System (IWSS) ensures an adequate, uninterrupted supply of makeup water to the CUP to generate chilled water or steam in the event of depressurization, a system maintenance interruption from Washington Suburban Sanitary Commission, or an emergency.** The IWSS increases chiller plant reliability so the CUP can provide chilled water to campus buildings for space conditioning.

› **The Thermal Energy Storage System (TESS)** increases energy efficiency by producing and storing chilled water during off-peak hours, which can then be used during daily peak chilled water demand. TESS also provides NIH with campus-wide emergency chilled water in the event of loss of power to the campus, improving efficiency and reliability and lowering operating costs.



› **The NIH Utility Distribution System** is an extensive underground network that distributes 1.8 billion pounds of steam per year. Utilities are distributed to NIH buildings through underground walkable tunnels (2 miles), concrete trenches (2 miles), natural gas lines (3.6 miles), domestic water lines (12 miles) and steam and chilled water pipes (over 7 miles). There are over 300 manholes and 450 domestic water valves located around the campus that facilitate inspection and maintenance of the NIH grounds utilities.

› **The Water Treatment System** is a fully updated automated water treatment and monitoring system used in the CUP to minimize the corrosive effects of water and biological agents on the metal surfaces inside the CUP cooling tower, chilled water system, steam generating systems, and other closed loop water systems. This helps prolong the life of these systems and maximizes their effectiveness. The system meets all state, federal regulatory, and NIH engineering and safety requirements to reduce energy consumption and improve water quality. A pioneering microbiological study has been carried out to evaluate the effectiveness of biocide by the rapid ATP detection technology.

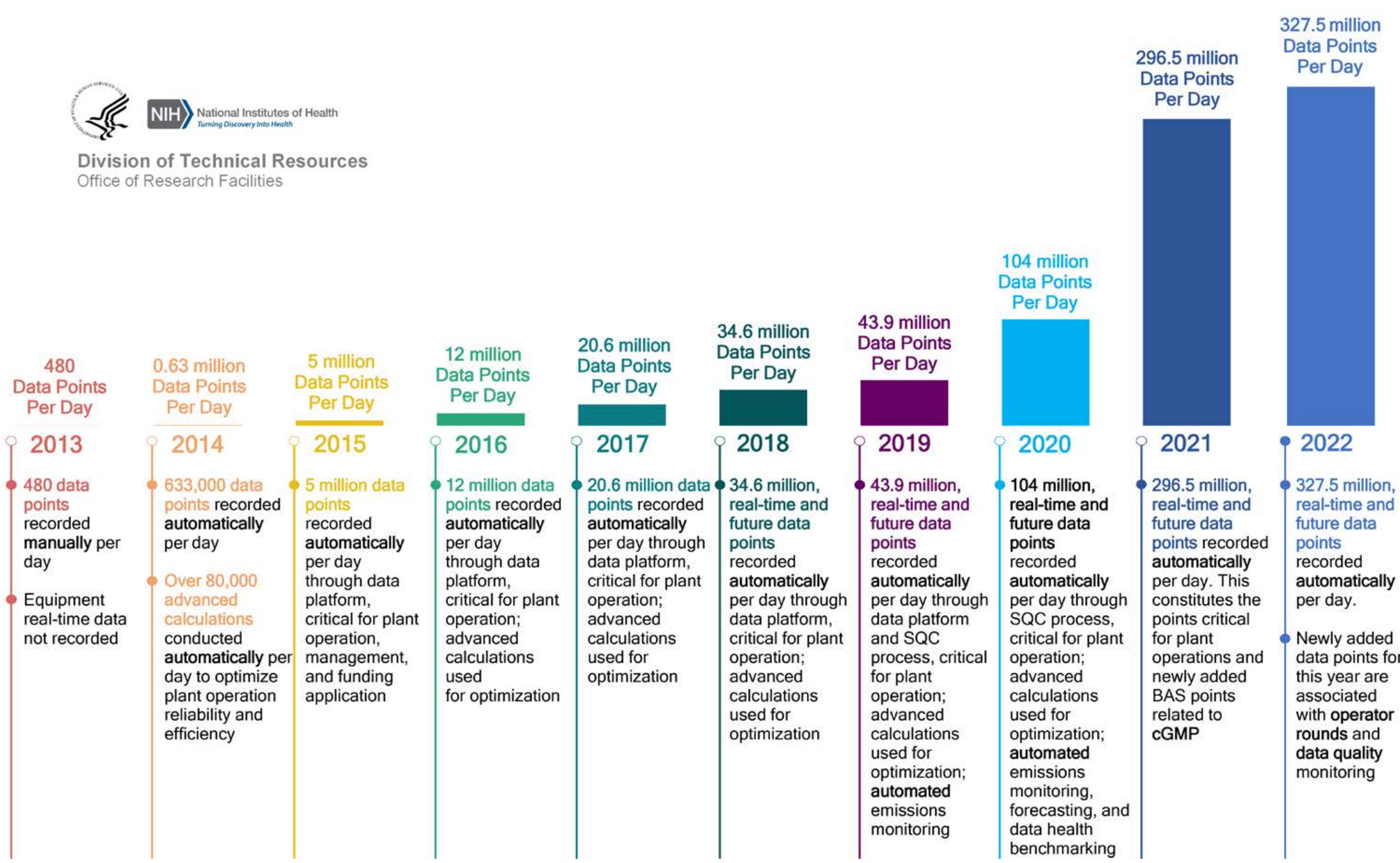
› **Control Room –** In order to ensure that all this intricate equipment runs 24/7 uninterrupted, it is monitored in a unique state-of-the-art control room. Over 327 million automated data points are collected each day from approximately 5,000 continuously running analyses and over 1,000,0000 calculations per day. This enables CUP to capture both positive and negative events in real time, allowing DTR to make instantaneous operating, risk, and maintenance assessments and decisions.

› **Asset Management –** The CUP uses a customized asset management program that captures data automatically from the source. The system greatly improves optimization, performance, productivity, reliability, operational uptime, accountability, and compliance. Asset management provides information to improve operational control including calibration; addresses safety concerns such as lockout/tagout; tracks history control and maintenance management and integrates training needs; tracks and provides notifications for inventory/purchasing; captures contracted work and chiller job plans; stores a library of documents for all major assets; defines and structures parts inventory; initiates triggers for notification and work order generation; assists with intra-agency collaboration; and provides 'live-time' reports for many other critical functions in the CUP. A handheld remote Mobility Program interfaces with the asset management program to assess equipment conditions to reduce mean time between failures and mean time to repair and track the Reliability Centered Maintenance Program.

› **Machine Learning (ML) Program –** Machine learning/artificial intelligence uses algorithms such as Classification, Logistic Regression, naïve Bayes, Support Vector Machines, and K-Nearest Neighbors to detect patterns or apply rules to categorize or catalog like items; predict likely outcomes or actions based on identified patterns; identify patterns and relationships; and detect unexpected behaviors.

› **Training & Simulation –** DTR provides regular mandatory and IACET-certified training programs for CUP professional staff to ensure that they maintain certifications and are cross-trained to become technical experts in CUP O&M. CUP training includes modules that emphasize the ability of CUP operators to handle abnormal and sometimes concurrent situations quickly and efficiently, as well as their ability to understand the whole plant as an integrated system to prevent equipment and collateral damage. Training and simulation provide operators with practice to adjust controls and immediately see the effects of their actions on the system they are controlling and on the rest of the plant.

Nih Central Utility Plant Real-time Data Collection



Utilities Generation Branch

UGB › Oversees the physical, mechanical, and electrical maintenance and operations of CUP systems for the generation of chilled water, steam, compressed air, and other utility needs.

› Oversees CUP training.

› Leads a continuous program that improves efficiency, accountability, reliability, security, safety, and cost effectiveness to improve CUP energy efficiency, reliability, and safety.

› Oversees CUP assets, inventory, documents, and work order management using a customized asset management system.

COGEN Plant Section

CPS › Operates, calibrates, and maintains the NIH Cogeneration Plant (COGEN).

› Ensures that NIH meets National Ambient Air Quality Standards.

› Purchases natural gas using complex financial analysis strategies that save the NIH millions of dollars annually.

› Conducts routine emissions tests, root cause analyses, corrective actions, and risk assessments related to mechanical failures and energy utilization.

Utilities Control and Maintenance Section

UCMS › Calibrates and maintains digital controls and monitoring equipment in conjunction with the Data Science and Artificial Intelligence Branch (DSAIB); reviews the controls that optimize plant operation to ensure that the boilers and chillers match established performance curves; oversees programming and start-up logic of new controls to optimize continuous operations.

Utilities Operations and Maintenance Section

UOMS › Operates the CUP 24/7/365 days a year.

› Performs preventive, predictive, and corrective maintenance on a scheduled and emergency basis for all CUP systems.

› Conducts Reliability Centered Maintenance (RCM). The RCM Program uses a structured framework for analyzing the functions and potential failure modes for physical assets in order to develop a maintenance task that will provide an acceptable level of operability, with an acceptable level of risk, in an efficient and cost-effective manner. Implementing the RCM program is crucial to ensure high reliability and peak performance of the CUP.

› Develops and revises SOPs for CUP functions.

Data Science and Artificial Intelligence Branch

DSAIB › Implements a data governance framework that incorporates and defines data management practices for the entire life cycle of DTR collected data.

› Provides effective approaches for stakeholders to collect, manage, and visualize structured and unstructured data.

› Implements a quality assurance policy and standard of procedures and develops computational approaches to manage data quality.

› Develops strategies, policies, and technologies to improve data's availability, consistency, trustworthiness, usability, integrity, and security.

› Promotes the use of data and computational technologies in management, decision making, root cause analysis, risk analysis, operation optimization, asset management, and maintenance.

› Provides data analytics expertise, services, and tools for stakeholders to achieve their missions.

› Works with stakeholders to gain insights in solving complex engineering issues through explorative studies of data and in-depth data mining.

› Incorporates DTR's engineering and facility operation expertise into computational and artificial intelligence approaches to deliver optimal solutions for complex issues.

› Tracks the advancement of artificial intelligence and machine learning technologies and promotes their applications in DTR management and operations of NIH facilities.

Utilities Distribution Branch

UDB › Operates, monitors, and maintains the CUP distribution systems (except electrical distribution) to ensure that utilities are delivered safely, efficiently, and optimally in accordance with established safety practices and State of Maryland environmental standards.

› Coordinates with outside utility providers and Building Unit personnel to ensure buildings and/or utilities are shut down safely for maintenance purposes.

› Monitors utility construction projects for safety; ensures that distribution system projects meet design and functional needs.

› Restores utility services during emergency shutdowns with minimal delay and downtime.

› Provides long term planning for utility distribution projects to replace aging infrastructure. Coordinates with the NIH Master Planning staff on future growth needs to ensure provision of adequate utility services.

› Reviews drawings for projects that affect utility distribution or for new connections to the distribution system.

Utilities Systems Design and Technical Services Branch

USDTSB › Provides architectural, engineering and construction management services required for planning, designing, acquiring, constructing, altering, renovating, improving, and repairing utility systems and other types of CUP facility projects.

› Consults during project formulation on program and project planning, including project concepts, schedules, estimates, and programs of requirements (POR).

› Monitors project progress against approved POR, budgets, and schedules.

› Implements project controls and risk management strategies to minimize variance from approved POR, budgets, and schedules.

› Communicates CUP project status, schedules, and costs to NIH management.

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Contact Us

Phone 301-435-8746

Visit us on the Web: www.orf.od.nih.gov/PoliciesAndGuidelines/Pages/default.aspx

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