

Arup capability

Process hazards, risk, and compliance



ARUP

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Visionary engineer Sir Ove Arup founded our firm on the belief that the best designs result from a holistic, multidisciplinary approach. More than a half-century later, Arup's process hazards, risk, and compliance work remains grounded in this philosophy.

The fundamental values of Ove Arup have also remained unchanged: to deliver quality while engaging in interesting and socially responsible work, and to display integrity in all dealings.

Introduction

Arup's industrial and laboratory process hazards/risk/compliance work combines chemical and fire engineering with process facilities operating experience to offer a unique, real-world blend of expertise to owners, facility managers, tenants and design teams.

Industrial and laboratory projects need an ongoing discussion of hazard issues between the code consultant, the design team, environmental, health, and safety, the owner/developer, the user groups, and the local building and fire code officials. We provide this level of involvement with all of the constituencies and groups to achieve a practical, unified design that results in a usable, operational building.

We have experience in a wide range of industrial manufacturing and laboratory facilities, including: flammable liquid processing, combustible solids handling, bio/pharmaceutical manufacturing, semiconductor/clean rooms, alternative fueling (H², CNG, LNG, biofuels), and bio-containment (BSL) laboratories.



Capabilities

- Alternative fueling and energy storage
- Codes, standards, and regulations
- Expert witness and incident investigation
- Explosion relief and suppression
- Fire-water risk assessment, spill control, and secondary containment
- Hazardous electrical classification
- Hazardous materials and dangerous goods
- Hazardous ventilation
- Industrial hygiene/environmental health and safety
- Modeling and analysis
- Professional registration/accreditation
- Process safety and hazards mitigation
- Risk assessment
- Specialty detection, alarm, and suppression systems
- Specialty occupancy design
- Site planning

Professional registration/accreditation

Arup's industrial manufacturing and laboratory process hazards, risk, and compliance offering combines chemical and fire engineering with process facilities experience. Our members are committed to high standards of engineering, proven with personal accreditations and qualifications that are supported and promoted from within the firm. In the words of our founder Sir Ove Arup, "Success depends on the people working in it and for it," a philosophy we carry forward to this day.

Arup has licensed and accredited engineers with a range of credentials, including:

- CEng
- CEnv
- IChemE
- NPER
- PE
- Professional Process Safety Engineer
- RPEQ



We have over 100 team members globally within our 88 local offices.

Established
in 1946

Multidisciplinary
consulting and design

IChemE Gold
Corporate partner

ISO 14001
QA-ISO 9001

Codes, standards, and regulations

Arup has experience working with a wide variety of codes and standards, ranging from chemical hazard regulations to building and fire code compliance as related to bio/pharma facilities and the specialized design features required for compliance and risk management. Arup designs to higher standards and finds balance between insurance, corporate, and legal requirements.

Our global reach allows for an extensive understanding of different regulatory bodies across a variety of countries. Arup is committed to meeting all statutory and regulatory requirements as well as every client's corporate engineering and environment, health, and safety standards.



Skills

- Good Manufacturing Practice (GMP)
- Cleanroom ISO standards
- Hazardous chemical handling regulations
- Dangerous goods standards
- Insurance and corporate risk mitigation requirements
- Building and fire-safety codes
- Drug, medicine, and healthcare regulations
- Animal by-product regulations
- Safety Health and Welfare at Work Act and regulations
- WHO lab quality standards
- HACCP principles
- Major Accident Prevention Policy

Specialty detection, alarm, and suppression systems

Arup determines appropriate active hazard mitigation system strategies and designs suppression and detection systems tailored to a facility's specific hazards. This includes gas and flame detection, notification and alarms for high-pressure systems, hydrogen and other liquefied or compressed gasses, flammable liquids or vapors, and lab fume hood alarms in relation to hazardous chemical venting.

Our work also includes special suppression systems to protect high-value equipment including water-mist and clean agent systems as well as AFFF systems that use PFOS-free concentrates.

Expert witness and incident investigation

Arup acts as the expert witness on specialized topics within the science, industry, and technology fields and provides incident investigation services.

Our experts comply with their duty to the court, their client, and any rules prescribed by their professional body. Arup has provided expert witness services to clients over many years. These services have a vital role in civil litigation and are provided in many discipline areas relating to many different project scenarios.

We have provided expert witness services at planning inquiries, water engineering expert witnesses, project finance advisory services, and insurance and project finance including due diligence. Arup experts perform risk assessment and management, dispute resolution and litigation, forensic investigation, and planning-related public inquiries.



High expansion foam test

Fire-water risk assessment, spill control and secondary containment

Arup offers comprehensive fire-water risk assessments to determine the risk of contaminated fire-water and, if appropriate, risk-reduction measures. Our fire-water risk assessment procedure complies with EPA guidance and comprises a review of the quantities of materials stored on site, their physical and toxicological properties and their storage facilities, consultation with the relevant fire authority, calculation of the maximum fire-water volume and coincident rainwater runoff, assessment of risk and of current provisions on site for the prevention of contaminated runoff, and the identification of potential risk-reduction measures, including fire-water retention facilities.

We also provide solutions to meet facility and regulation requirements for spill control and secondary containment of fire-water for specialized occupancies.



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Hazardous ventilation

Arup specifies and designs hazardous exhaust systems including appropriate location, segregation, manifolding, and interlocks based on the hazard present. Arup works to all hazardous gas regulations, such as DSEAR, to ensure that a facility's ventilation design complies with all regulatory requirements.

Our experts work to reduce occupational exposure risk to facilities personnel in areas of hazardous ventilation. We provide design of both passive and active safety systems to protect facilities, their operators, and the public surrounding areas.

We survey existing plant assets for any potential hazardous release and practical ventilation provisions, identifying remedial works.

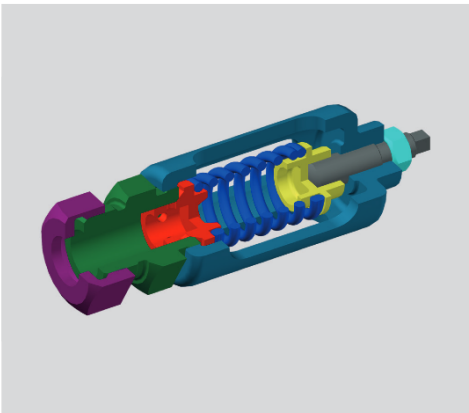
Explosion relief and suppression

We specify mitigate deflagration and detonation hazards, meeting both local code and insurance requirements. Arup specifies mitigations which reduce explosion risk to employees, including explosion prevention, explosion relief, and explosion suppression.

Our firm also designs buildings capable of withstanding the pressure generated from an explosion, ensuring the protection of indoor and outdoor client assets. We perform quantitative risk analysis of BLEVEs, VCEs, and pool fires to develop threat barrier diagrams and recommendations for siting of bulk chemical storage, as well as active and passive mitigation systems to reduce the likelihood of an explosion.



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Hazardous electrical classifications

The Arup team prepares explosion protection documents for clients under the ATEX, IEC, and NEC/NFPA directives. We assess electrical equipment in dangerous atmospheres, provide alternative methods for declassification, and advise clients on maintenance for such equipment.

Our experts identify possible sources of static charge accumulation such as flammable liquid flow and recommend methods to minimize and dissipate static charge accumulation. Arup uses protection techniques for electrical equipment following NFPA, IECEx, and ATEX standards, defining equipment protection levels for hazardous electrical equipment.

Arup guides the appropriate selection of electrical equipment for use in hazardous electrical zones based on defining equipment protection levels, temperature classification in relation to ignition temperatures, the subclassification of apparatus, and apparatus construction and enclosure in relation to process area conditions. We develop the plan and section drawings that delineate the electrically classified locations and corresponding levels of protection.

We analyze NEC vs. ATEX vs. IEC electrical equipment approvals and advise clients on suitability for use on relocation to a different country.



Skills

- ATEX
- IEC
- NEC hazardous areas
- Static ignition mitigation
- NFPA 77, 496, 497, 499



Specialty occupancy design

Arup is well-versed in specialized occupancy design for facilities storing and using hazardous materials posing flammability risks and/or biohazards, as well as other regulated substances. Our staff is experienced in the design of clean manufacturing and research areas in biologics and pharmaceuticals facilities and understands the requirements of different biosafety levels and clean room classifications.

We also have expertise in the renovation of existing buildings to new laboratories and production areas. We understand the requirements of the existing building structure and codes, as well as the new sterility and ventilation requirements associated with biopharmaceutical facilities. During concept design, Arup staff identify where control areas and high-hazard occupancies are necessary and provide critical information to design teams.



Skills

- High-Hazard Group H/Protection level occupancies
- WHO NH bio safety levels (BSLs)
- Cleanroom classification design (ISO)



Process safety and hazards mitigation

Arup provides comprehensive bases of safety for hazardous facilities and processes. Arup undertakes critical and collaborative safety reviews for existing and new facilities and their control systems and specifies safety requirements and recommended best practices. Arup improves the operational safety of facilities, complying with all regulatory commitments.

We prepare and update facility safety reports, demonstrating that all measures have been taken to prevent major accidents. Arup prepares and reviews emergency plans and procedures, considering the key risks to persons within the facility.

Arup develops functional safety plans by performing assessments of safety-critical systems, in line with standards (IEC61508), as well as safety integrity level determination and verification.



Skills

- Functional safety development
- Safety case development and assessment—
COMAH, MHF (Australia/New Zealand)
- Emergency procedures



Modeling and analysis

Arup provides modeling and analysis for science, industry, and technology facilities to assist with incident management, risk, and the management of chemical hazards.

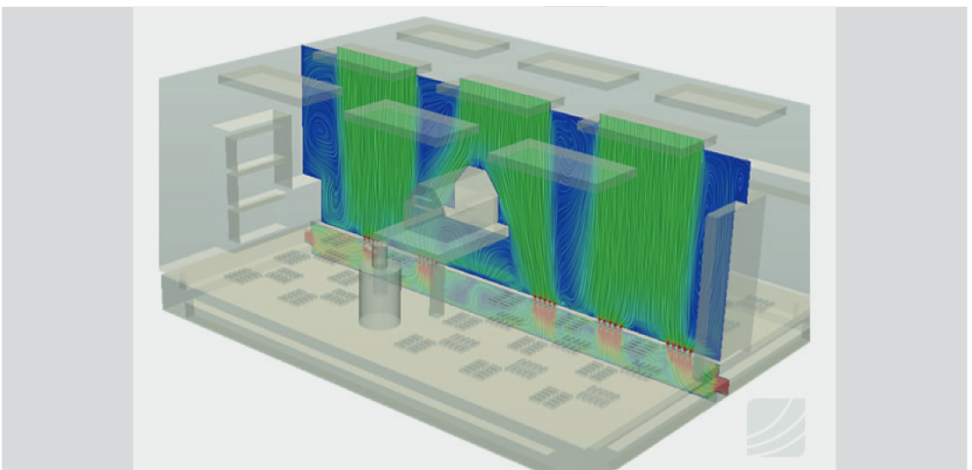
We have invested in numerous modeling software licenses to provide our clients with up-to-date methodology and data sources. Our engineers use analytical techniques including computational fluid dynamics to model hazardous chemical releases and consequences. Our simulation approach combines mathematical data modeling and deep engineering knowledge to draw conclusions about the current and future state of an asset.

Our engineers analyze potential environmental and safety impacts due to major accidents deriving from a system's vulnerability to natural and man-made (process) risks. Arup defines a facility's adaptive capacity and determines the magnitude of impact of a major accident and reasonable worst-case scenarios. We use the "as low as reasonably practicable" (ALARP) principle to minimize risk.



Skills

- Software capabilities: PHAST, FRED, Air3D, FLACS, XFMEA
- Explosion modeling, prevention and mitigation; overpressure scenario identification
- Toxic and flammable gas dispersion; chemotoxic assessment and gas monitoring
- Spill and release modeling and analysis
- Major accident scenarios
- Pressure safety/thermal relief valves
- Process Hazards Assessment (PHA)



Risk assessments

Arup facilitates process hazards reviews, which apply risk-based decision-making for process/facility design and operation. Our work includes the identification of hazards, assessment of risk, and evaluation of prevention, detection, control, and mitigation measures. Arup performs quantitative risk analysis, which includes review of past events and determination of how the hazards and risks developed. Our teams justify risk priorities and develop risk ranking matrices.

Our experts also facilitate all HAZOP stages, focusing on process safety through all stages of design. Our engineers contribute to robust designs via the analysis of risks to safety, the environment, performance, and reliability. We provide system reliability and availability analysis by identifying shortfalls against set targets.

We understand mission-critical items to study, with a goal of limiting system down time. We frequently utilize failure modes and effects analysis (FMEA) for system reliability and availability studies.



Skills

- Hazard studies, HAZOP and CHAZOP — Chair and Scribe
- Quantitative risk assessment — LOPAs, Safeti, Bow Tie, fault and event trees, ALARP
- Qualitative risk assessment — FMEAs, FMECAs, what-ifs, ALARP, RAGAGEP
- DSEAR — Risk assessment, hazardous area classification, equipment selection, verification
- Reliability and availability engineering
- Dust hazard assessments (DHAs)
- Occupied building risk assessments (OBRA)

Industrial hygiene/environmental health and safety

Arup reviews machinery compliance against relevant codes and standards, advises on technical and organizational risk reduction measures, and consults on appropriate methods for hazardous waste disposal.

Our engineers provide hazardous waste identification, classification, transport, and disposal requirements and design for storage and handling facilities.

We design safety management systems in line with Seveso III and COMAH directives. We also perform machinery safety and evaluation by review of CE compliance and other relevant directives and standards, produce machinery risk assessments, and provide advice on technical and organizational risk-reduction measures.



Skills

- Hazardous waste disposal
- Safety management systems
- Machinery safety and evaluation
- Outdoor bulk hazardous gas liquid storage installations



Site planning

Arup engineers perform site-specific seismic hazard assessments for projects in Europe, the Middle East, Central Asia, the Caribbean, South East Asia, Australia, and the Americas. Arup carries assessments of ground motion hazards based on geological, tectonic, and seismological information. Arup geologists and engineers have an international reputation for identifying and mitigating these natural hazards. Services relating to earthquake hazards include slope stability assessment, evaluation of fault activity, liquefaction assessment, seismo-tectonic evaluations, and seismic geology.

We perform wildfire assessments by reviewing case studies and undertaking in-house wildfire research. We identify the key factors affecting wildfire risk and the potential for spread and further ignitions. We utilize wildfire exposure methods, models, detection, tracking, and standards to assess potential ignition and fire propagation to buildings and other exposures from brands, radiation, and convected heat. Wildfire exposure analysis and risk mapping is used as input to the planning of cities, communities, and individual properties, as well as infrastructure design and construction.

Arup assists operators of Seveso major accident hazard establishments to meet the statutory requirements, including preparation of risk assessments, notification of commencement of construction and operation, preparation of major accident prevention policies, safety reports and standard operating procedures, and assessment of impacts.



Skills

- Seismic studies
- Natural disaster impacts
- Wildfire assessments
- COMAH/Seveso/major hazard facility consulting

Hazardous materials and dangerous goods

Arup provides safety solutions for facilities working with a wide range of hazardous materials types, meeting applicable regulations and best practices for chemical handling.

Arup's experts design approaches for hazardous materials storage and use including the location and layout of storage facilities, identification of flammable materials, and identification and classification of leak sources. Our engineers predict the consequences of loss of containment of hazardous materials and model the releases of hazardous gases, vapors, and liquids as they relate to fire, explosion, toxicity, and oxygen depletion hazards.



Skills

- Flammable and combustible liquids
- Flammable/pyrophoric gases
- Oxidizers /reactives
- Combustible dusts
- Reactive metals
- Flammable solids
- Explosives
- Highly toxic/toxic materials
- Corrosives
- Radiological hazards
- Cryogenic materials



Alternative fueling and energy storage

Arup provides compliance and risk-based approaches for the protection of lithium-ion batteries and CNG, LNG, and hydrogen storage and fueling.

We review battery charge/discharge fire and explosion prevention strategies and fire-suppression system options for lithium-ion battery energy storage systems. Our engineers also prepare fire-protection reports for lithium battery production and storage facilities.

Our team performs battery container system evaluations and design reviews of battery system safety, ensuring compliance with applicable laws and regulations. Our engineers consult on codes and hazards as related to hydrogen storage and fueling, including both gaseous and liquified hydrogen.

Arup has also performed feasibility studies on generating and using hydrogen at multiple facilities, including reviewing hydrogen road maps and the feasibility and phasing of hydrogen transport.



Skills

- Lithium-ion and other BESS
- Hydrogen
- CNG, LNG
- Biofuels



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Amgen

Amgen continues to be a key pharmaceutical client for Arup since the start of our working relationship 20 years ago. Arup's work with Amgen includes feasibility studies for new manufacturing plants, analysis of FM Global data sheets vs. risk reduction impact, new laboratory design, fire suppression, detection and alarm design for high-value equipment, process hazards analysis, and risk assessments.

Amgen is one of the world's leading biotechnology companies, with over 22,000 employees worldwide and a total revenue exceeding \$23bn. Amgen manufactures medicines for patients with serious illnesses, focusing on areas of unmet medical need to provide solutions to both improve health and improve people's lives.

Project locations:

- South San Francisco, CA
- Thousand Oaks, CA
- Cambridge, MA
- West Greenwich, RI
- Sao Paulo, Brazil
- Burnaby, Canada
- Munich, Germany
- Dun Laoghaire, Ireland
- Istanbul, Turkey
- Singapore, Malaysia



Amgen headquarters
Thousand Oaks, CA

Rolls-Royce

For over 20 years, Arup has provided consultancy services to Rolls-Royce, including process safety reviews of hazardous materials, feasibility studies of alternative heating, and design of compressed air installations.

With services across civil aerospace, defense, and power systems, Rolls-Royce develops innovative technologies to deliver clean, safe, and competitive solutions for global power needs. With a total revenue of £11.8bn, 50,000 employees, operations in more than 50 countries, and customers in over 100, Rolls-Royce remains one of Arup's most valued clients.

Project locations:

- Indianapolis, IN
- Mississippi, MN
- Mount Vernon, OH



Rolls Royce factory
Derby, UK

MSD

Arup has had an established relationship with MSD for more than 20 years, providing process hazards review, fire-safety strategy, high-value asset protection, and engineering design for chemical storage and use in a new chemistry laboratory and support facilities.

With 74,000 employees, \$13.6bn invested in research and development in 2020, and \$3.1bn total philanthropy, MSD is one of the world's largest pharmaceutical companies. For 130 years, MSD has designed and manufactured lifesaving medicines and vaccines for some of the world's most challenging diseases and is committed to continuing their research in the prevention and treatment of life-threatening diseases.

Project locations:

- Haarlem, Netherlands
- Cambridge, MA



MSD
Haarlem, NL

Tesla

Tesla has worked with Arup since 2007, with project types including process hazards assessments, hazardous materials storage safety assessments, and the analysis of chemical processing operations for presentations to local building and fire officials.

Aligned with Arup's own commitment to sustainability, Tesla's mission is to accelerate the world's transition to sustainable energy and clean transport. As of 2020, Tesla has produced over 1M electric cars and had a total revenue of \$31.54bn, cementing their place at the forefront of clean energy and transportation.

Project locations:

- Fremont, CA
- Sparks, NV



Tesla gigafactory
Storey County, NV

Additional key clients

- Allergen Pharmaceutical
- Amazon Web Services
- Amazon Fulfillment
- AMRI Global
- Anika Therapeutics
- Animal and Plant Health Agency (APHA)
- Baxter Healthcare
- Bristol Myers Squibb
- CWP Renewables
- DSM Biomedical
- Dwr Cymru Welsh Water
- Essilor
- Fujifilm
- Irish Cement, Ltd
- Loctite
- Mizkan
- Origin Energy / Star Scientific
- Pfizer
- Port of Auckland
- Repligen
- Sellafeld Ltd.
- Sumitomo Electric
- Yorkshire Water Services

AstraZeneca

Arup has maintained a relationship with AstraZeneca for over 15 years, during which Arup provided engineering design services for new laboratory and research centers, site planning and feasibility studies, CHP technical advice, and fire strategies for chemical storage and use in AstraZeneca's lab facilities.

AstraZeneca is a biopharmaceutical business known for innovating medicines and vaccines and delivering to patients worldwide. In 2020, AstraZeneca had a total revenue of \$26.6bn, with 76,100 employees globally and sales in over 100 countries.

Project locations:

- Cambridge, UK
- Yorkshire, UK



AstraZeneca HQ
Cambridge, UK

Alaka'i Technologies

Arup's commitment to future technologies is well demonstrated in our work with Alaka'i Technologies, for whom we continue to provide process hazards review, risk, and compliance consulting for liquid and gaseous hydrogen storage and fueling, as well as detection and alarm design services.

Founded in 2006, Alaka'i Technologies designs and manufactures aircrafts powered by hydrogen fuel cell technology and is responsible for the development of the world's first hydrogen fuel cell powered aircraft.

Project locations:

- Hopkinton, MA
- Stow, MA



Alaka'i Technologies
Stow, MA

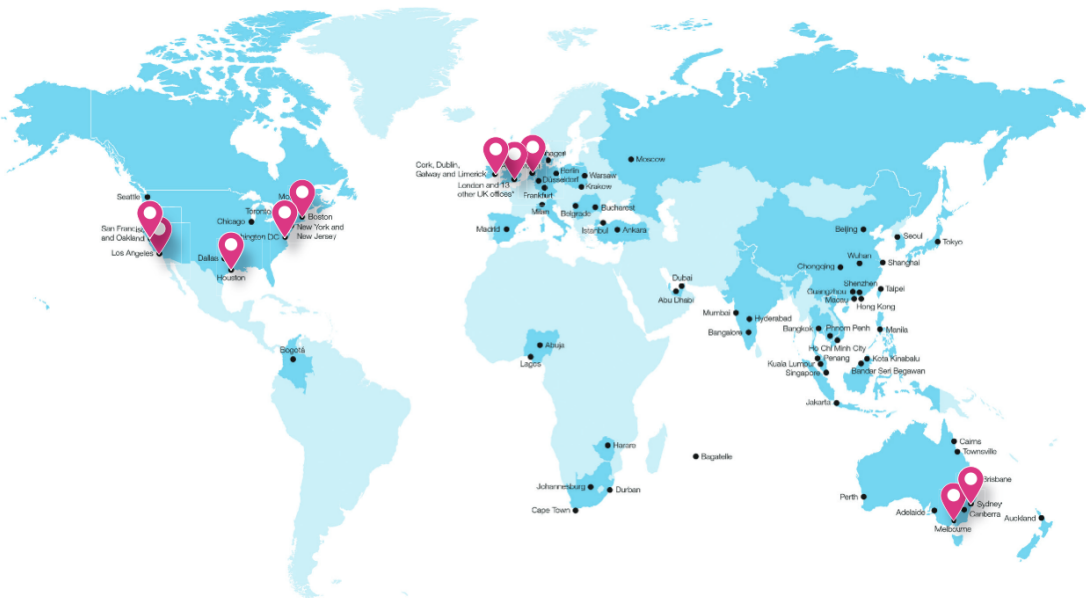
Centers of excellence

Our fundamental goal is to achieve excellence in all we do by bringing together the best professionals in the world to meet our clients' needs.



Arup centers of excellence:

- Amsterdam, Netherlands
- Boston, MA
- Cork, Ireland
- Dublin, Ireland
- Houston, TX
- Leeds, UK
- London, UK
- Los Angeles, CA
- Melbourne, Australia
- Midlands, UK
- San Francisco, CA
- Sydney, Australia
- Washington, DC



*Belfast, Bristol, Cardiff, Edinburgh, Glasgow, Leeds, Liverpool, Manchester, Midlands Campus, Newcastle, Nottingham, Sheffield, Winchester

Our values

Arup's values are derived from the beliefs and convictions of our founder, the engineer and philosopher Ove Arup. These values define and unite Arup's people and guide us in our work.

- Commitment to quality
- Total architecture
- Humane organization
- Straight and honorable dealings
- Social usefulness
- Prosperity of members

Great design comes from a commitment to quality, creativity and multidisciplinary collaboration. Arup's reputation for design excellence is evidence of our abiding belief in all three.

Our employee-owned structure promotes ongoing investment in joint research to yield better outcomes for clients and partners. Arup's culture looks a lot like the future: globally-connected, locally-focused and radically innovative.



About Arup

Arup is a global firm of planners, designers, engineers and business consultants, providing a diverse range of professional services to clients around the world. Founded in 1946 with an enduring set of values, our unique trust ownership fosters a distinctive culture and an intellectual independence that encourages collaborative working.

We are the creative force behind many of the world's most innovative and sustainable designs. Our firm has 14,000 employees working in more than 88 offices in over 33 countries. Arup is a firm that strives to make a difference.

As designers of the built environment, we have a great responsibility to ensure that our contribution leaves a lasting, positive legacy. Where inspiration is concerned, our vision of what constitutes design evolves with and augments, the rapidly changing needs and issues of people across the world. Creativity, innovation, and technical excellence, are, in our view inherent to the design process.



Total design

Total design is the integration of the design and construction process and the interdependence of all the professionals involved; the creative and innovative nature of engineering design; the value of ingenuity and invention and the social purposes of design.

Arup is a global design and business consulting firm. Outstanding solutions, innovation, and value characterise our work. As professional consultants we have a vast pool of technical expertise across the world, enabling us to achieve the best possible results for our clients.

Ove Arup founded his practice in London in 1946. Sir Ove's ideals and principles were, and are, driving forces within the firm. Foremost among his beliefs are "total design" and the social purpose of design.

By 1976, Arup's reputation had become truly global with the completion of the Sydney Opera House. To maximize the global best practice knowledge pool within Arup, we operate virtual skills networks, extranet portals, secure networks and collaborative project teamwork. This makes us unique in our ability to derive innovative solutions by pulling from diverse minds around the world for our clients.

Arup's creative spark and intellectual independence was present from the very beginning. Today, our staff members continue to be driven by our founder's restlessness with the tried and tested. This attitude is behind our pursuit of technical excellence and willingness to invest in research and innovation.

The firm is held in trust on behalf of its employees to ensure that Arup retains its independent spirit and remains a learning organisation. By delighting our clients, being true to our principles, and putting our skills to work for a positive social impact, Arup continues to shape a better world.

Arup made its name in the twentieth century as the designer and engineer behind some of the world's most ambitious structures. Playing an influential part in the evolution of the built environment for over seventy years, we add to that proud history each and every day.



Sydney Opera House
Sydney, Australia

We shape a better world

Arup is the creative force at the heart of many of the world's most prominent projects in the built environment. We offer a broad range of professional services that combine to make a real difference to our clients and communities.

We are a truly global firm. From 88 offices in 33 countries, our 14,000 planners, designers, engineers, and consultants deliver innovative projects across the world with creativity and passion. Founded in 1946, our unique trust ownership and enduring values foster a distinctive culture and an intellectual independence that encourages collaboration. This is reflected in everything we do, allowing us to develop meaningful ideas, help shape agendas, and deliver results that frequently surpass our clients' expectations.

Multidisciplinary services

Acoustic consulting • Audiovisual consulting • Bridge design • Building design
Chemical engineering • Civil engineering • Construction planning • Controls and commissioning • Cost management Development planning • Electrical engineering
Energy consulting • Environmental consulting • Façade engineering
Fire/life safety consulting • Geotechnical engineering • Highway engineering
Impact and blast engineering • IT and communications consulting • Lighting design
Logistics consulting • Management consulting • Maritime engineering
Mechanical engineering • Offshore engineering • Plumbing engineering
Project management • Rail engineering • Risk consulting • Security consulting
Seismic design • Structural engineering • Sustainability consulting • Transaction Advice
Transport planning • Tunnel engineering • Venue consulting • Visualization and modeling
Water engineering • Wind engineering

Americas offices

Bogotá • Boston • Chicago • Dallas • Houston • Los Angeles • Montreal • New Jersey
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