भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

# ME 1050 -Basics of Mechanical Engineering

## Dec 2021

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# Course syllabus

An introduction to Mechanical Engineering; Disciplines of mechanical engineering; A quick exposure on the broad areas of mechanical engineering: statics, dynamics, kinematics, solid & fluid mechanics, thermodynamics, mechanical design, material science, computer-aided manufacturing; Research areas in mechanical engineering

# Text Books:

- An Introduction to Mechanical Engineering, Jonathan Wickert and Kemper Lewis, Cengage Learning
- 1800 Mechanical Movements, Devices and Appliances, Gardner Hiscox, Dover Publications
- Machines That Made History: Landmarks in Mechanical Engineering, Jennifer Black, ASME History and Heritage Committee
- An Introduction to Mechanical Engineering, Part-1 and Part-2, Clifford et al., Hodder Education, UK
- Vector Mechanics for Engineers: Statics and Dynamics, Beer et al., McGraw Hill Education
- Fluid Mechanics, Kundu et al., Academic Press

# Class Hours (3-1.5-0-2)

**Class Hours**
Lectures: Tuesday (16:00-17:30 hrs) & Friday (14:30-16:00 hrs) Q slot- Online

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# Grading policy (Tentative)

- 20 % – Quiz-1 (1-2 segment)
- 20 % – Quiz-2
- 20 % – Quiz-3
- 30 % – Presentation (Group of 4)
- 10 % – Attendance – Binary system 10/0 – Maximum 2 classes one can bunk (medical leave is considered provided medical certificate is produced)

# What is Engineering?

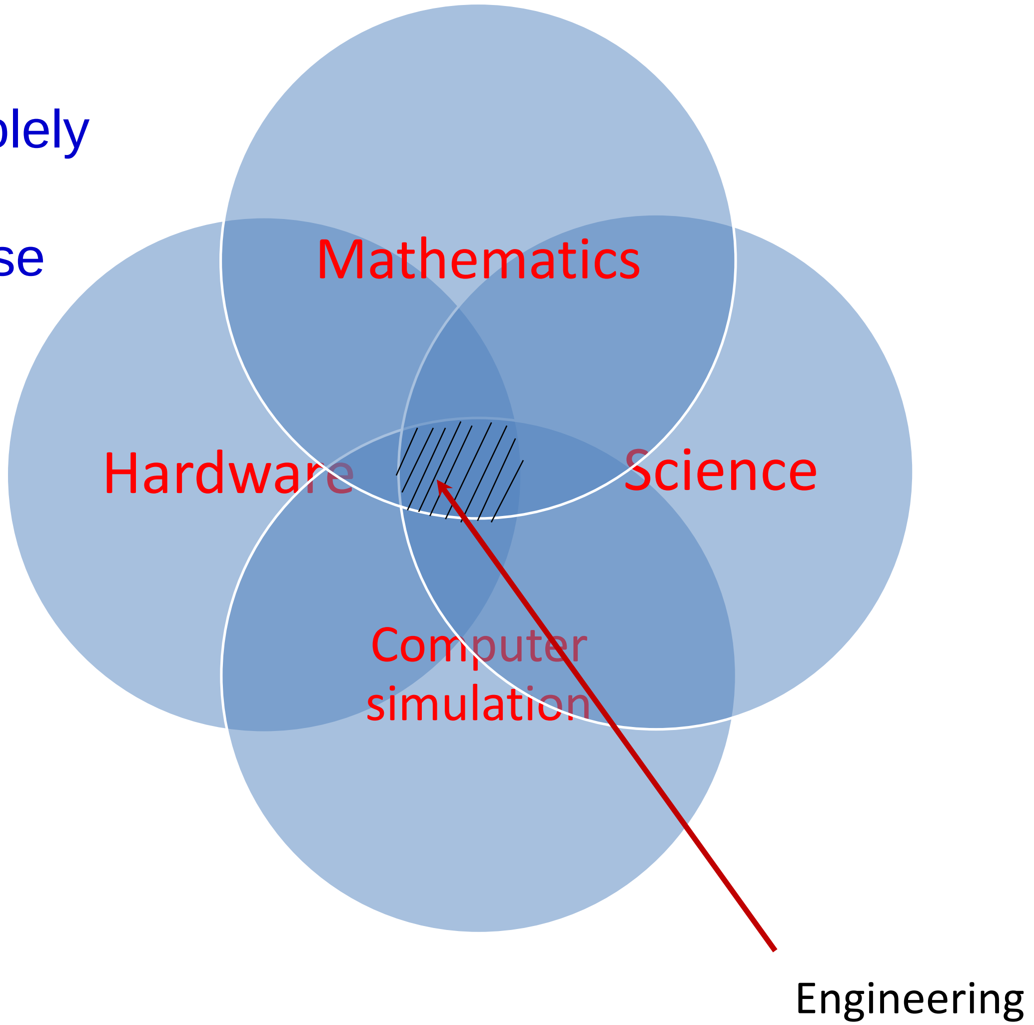
The word “engineering” derives from the Latin root **ingeniere**, meaning to design or to devise, which also forms the basis of the word “ingenious.” Those meanings are quite appropriate summaries of the traits of a good engineer.

At the most fundamental level, engineers apply their knowledge of mathematics, science, and materials—as well as their skills in communications and business—to develop new and better technologies.

An Introduction to Mechanical Engineering, Jonathan Wickert and Kemper Lewis, Cengage Learning

# Contd…

Rather than experiment solely through trial and error, engineers are trained to use mathematics, scientific concepts, and computer simulations as tools to create faster, more accurate, and more economical designs.



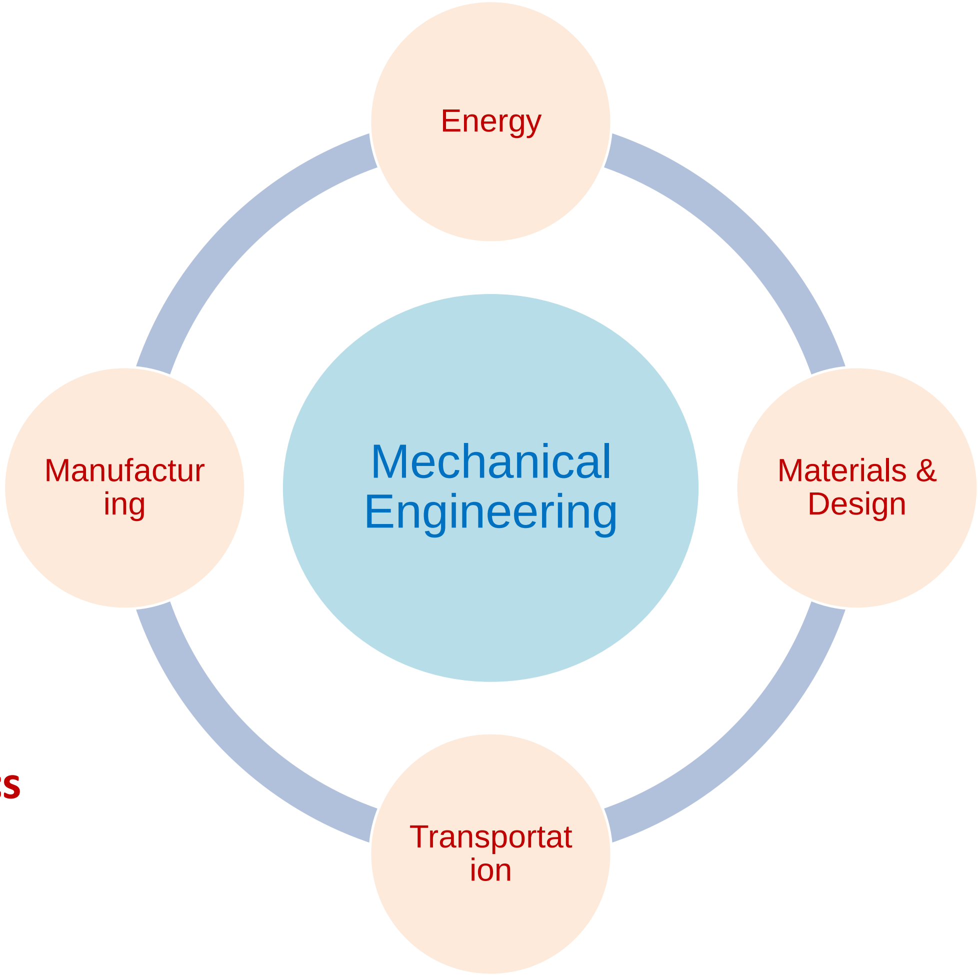
- In that sense, the work of an engineer differs from that of a scientist, who would normally emphasize the discovery of physical laws rather than apply those phenomena to develop new products.
- Engineering is essentially a bridge between scientific discovery and product applications.
- Engineering does not exist for the sake of furthering or applying mathematics, science, and computation by themselves.
- Rather, engineering is a driver of social and economic growth and an integral part of the business cycle.

# Who is a mechanical engineer?

The U.S. Department of Labor describes the profession as follows:

"*Mechanical engineers research, develop, design, manufacture and test tools, engines, machines, and other mechanical devices. They work on power producing machines such as electricity-producing generators, internal combustion engines, steam and gas turbines, and jet and rocket engines. They also develop power-using machines such as refrigeration and air-conditioning equipment, robots used in manufacturing, machine tools, materials handling systems, and industrial production equipment.*"

# Major Domains in Mechanical Engineering




**AI & Data Analytics**

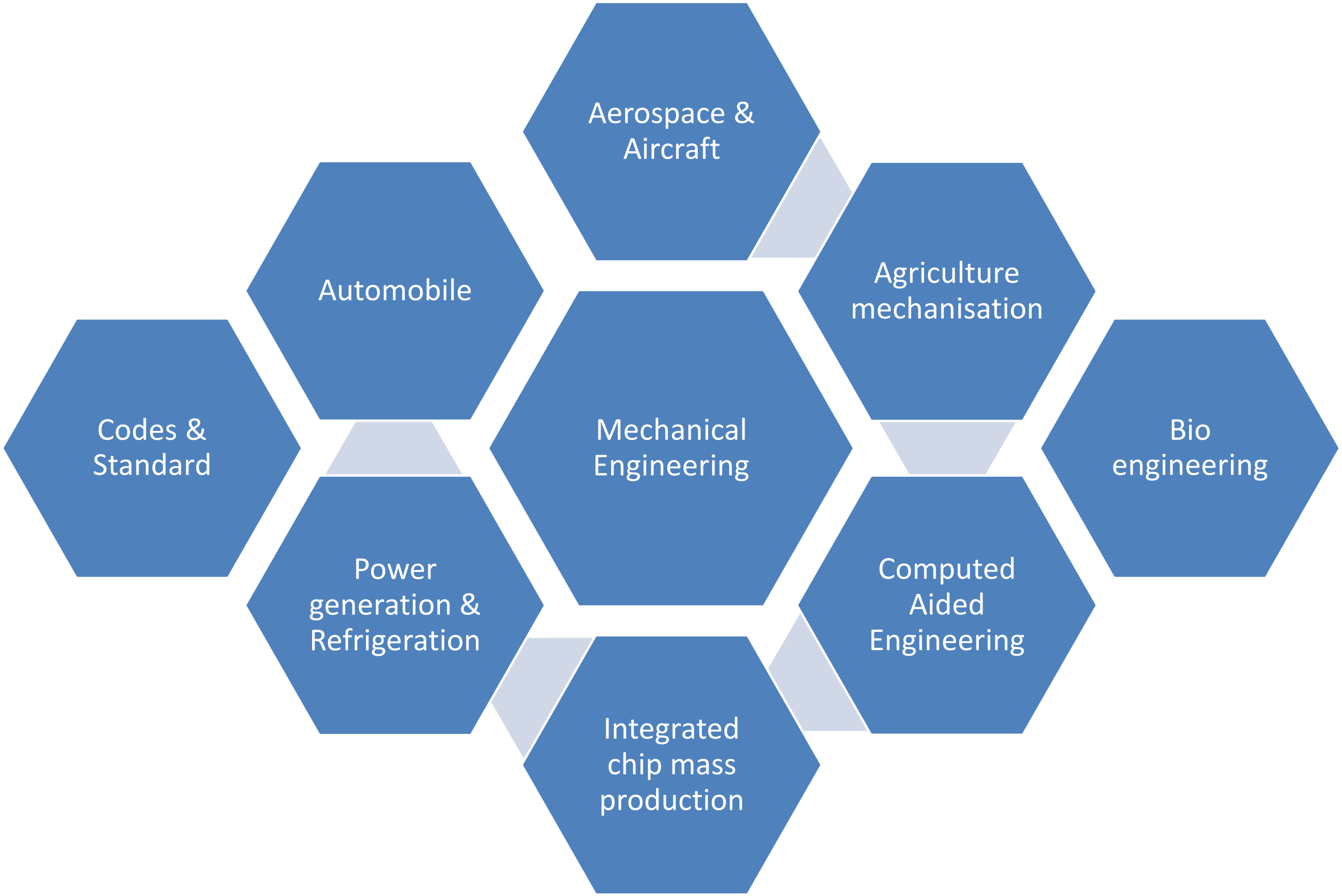
# Expertise of a mechanical engineer

Mechanical engineers are known for their broad scope of expertise and for working on a wide range of machines. Just a few examples include the microelectromechanical acceleration sensors used in space vehicle gyroscope; heating, ventilation, and air-conditioning systems in office buildings; land, ocean, and space robotic exploration vehicles; heavy off-road construction equipment; hybrid gas-electric vehicles; gears, bearings, and other machine components; artificial hip implants; deep-sea research vessels; robotic manufacturing systems; replacement heart valves; noninvasive equipment for detecting explosives / defects in components; and interplanetary exploration spacecraft.

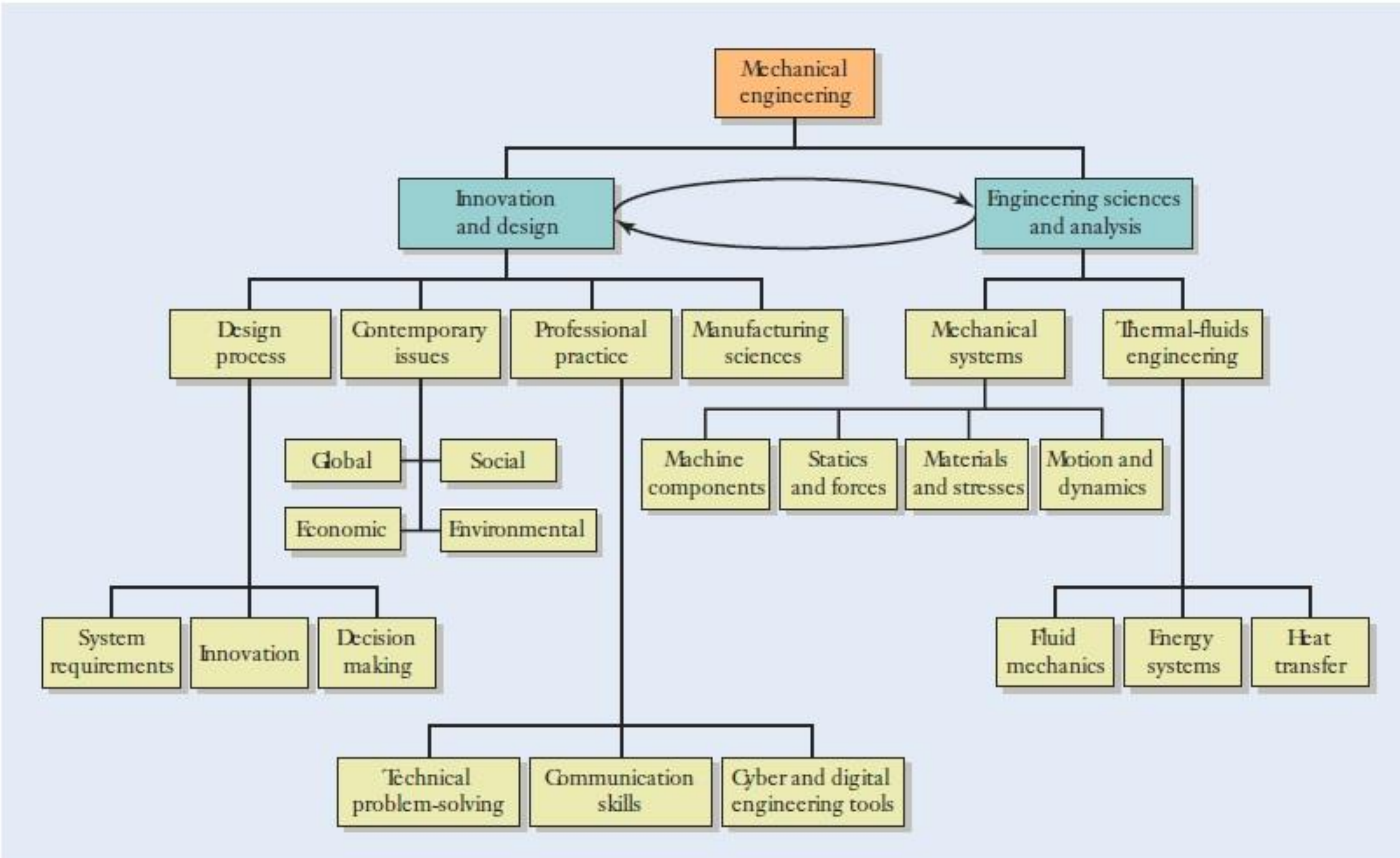
While mechanical engineering often is regarded as the broadest of the traditional engineering fields, there are many opportunities for specialization in the industry or technology that interests you. For example, an engineer in the aviation industry might focus her career on advanced technologies for cooling turbine blades in jet engines or fly-by-wire systems for controlling an aircraft's flight.

Above all else, mechanical engineers realise hardware that works and it's intended function. The developed product must be economically viable and should benefit mankind.

# Main contributions

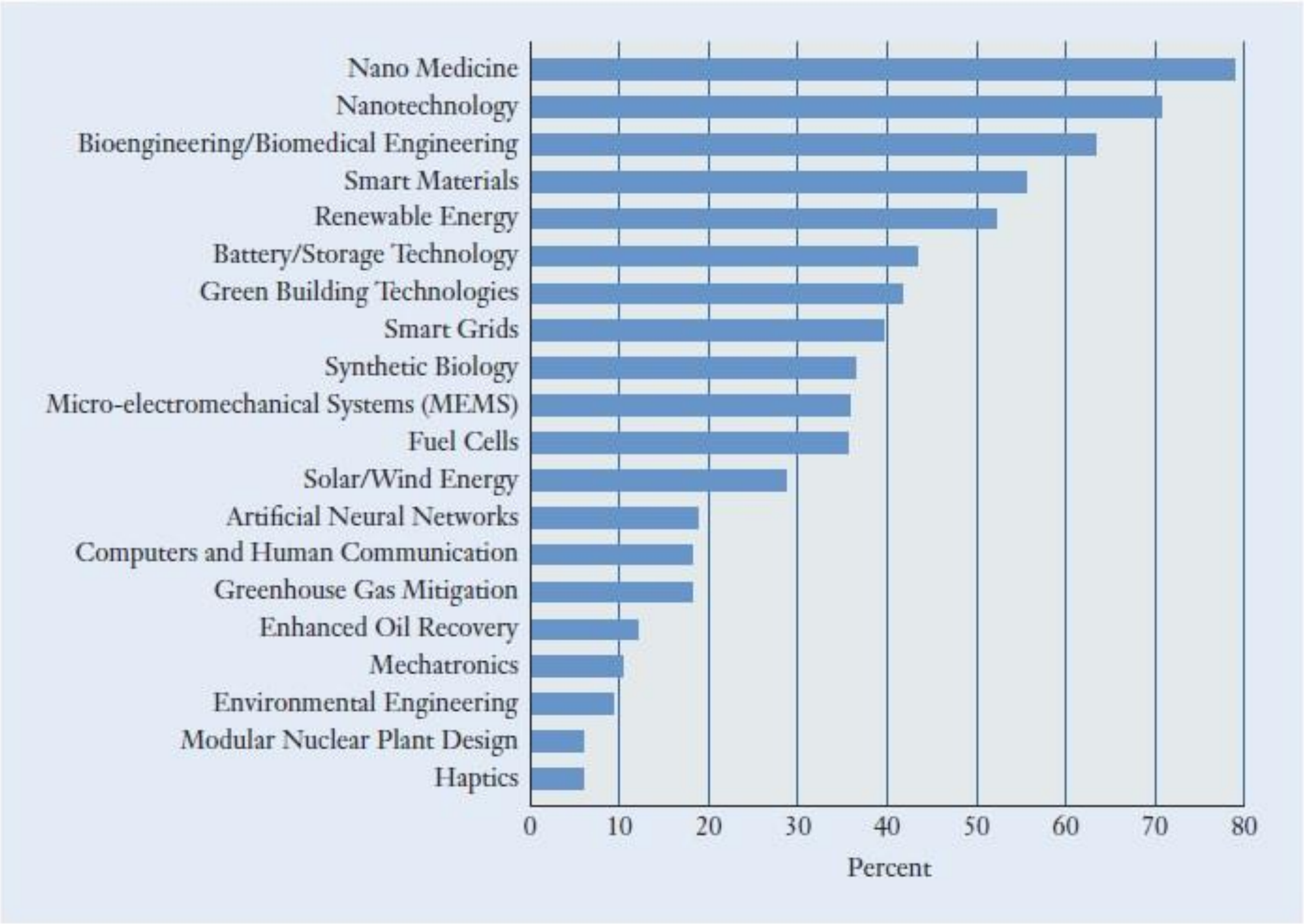


# Program of study




An Introduction to Mechanical Engineering, Jonathan Wickert and Kemper Lewis, Cengage Learning

# Emerging Areas




An Introduction to Mechanical Engineering, Jonathan Wickert and Kemper Lewis, Cengage Learning

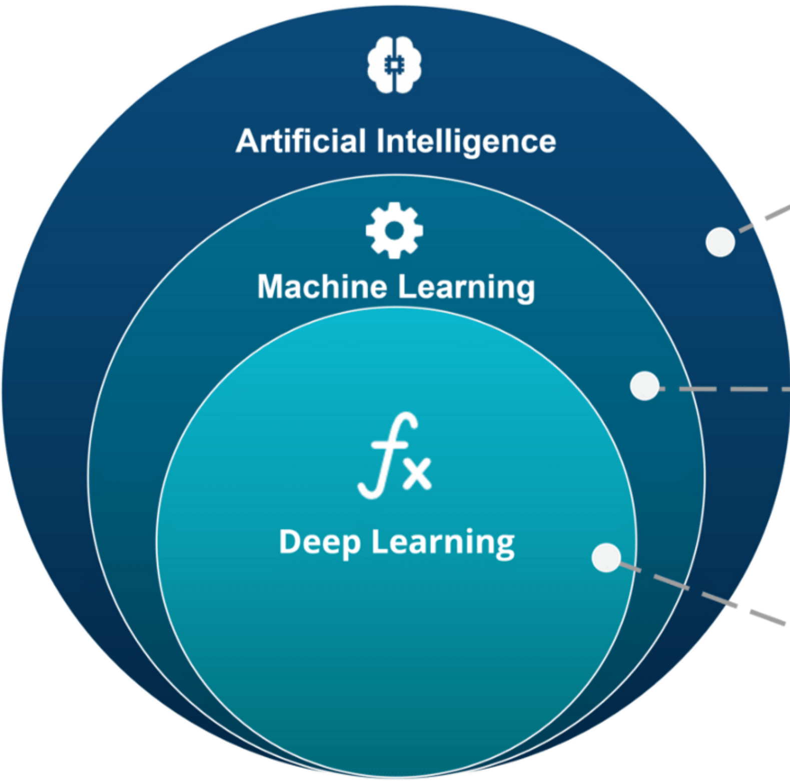
# Career Opportunities

- Design and analyze any component, material, module, or system for the next generation of hybrid vehicles
- Design and analyze medical devices, including aids for the disabled, surgical and diagnostic equipment, prosthetics, and artificial organs
- Design and analyze efficient refrigeration, heating, and air-conditioning systems
- Design and analyze the power and heat dissipation systems for any number of mobile computing and networking devices
- Design and analyze advanced urban transportation and vehicle safety systems
- Design and analyze sustainable forms of energy that are more readily accessible by nations, states, cities, villages, and people groups
- Design and analyze the next generation of space exploration systems
- Design and analyze revolutionary manufacturing equipment and automated assembly lines for a wide range of consumer products
- Manage a diverse team of engineers in the development of a global product platform, identifying customer, market, and product opportunities

# Contd…

- Provide consultant services to any number of industries, including chemical, plastics, and rubber manufacturing; petroleum and coal production; computer and electronic products; food and beverage production; printing and publishing; utilities; and service providers
- Work in public service for such governmental agencies as the Indian Space Research organisation, Defense Research Development Organisation, Bureau of Indian Standards, National Institute of Standards, Environmental Protection Agency, Railways, Oil Companies, Power sector and National research laboratories.
- Pursue a career in academics – teaching & research

# Artificial Intelligence




**ARTIFICIAL INTELLIGENCE**
A technique which enables machines to mimic human behaviour

**MACHINE LEARNING**
Subset of AI technique which use statistical methods to enable machines to improve with experience

**DEEP LEARNING**
Subset of ML which make the computation of multi-layer neural network feasible

Courtesy: edureka

# Energy

Renewable Energy

Coal and Natural Gas

Energy

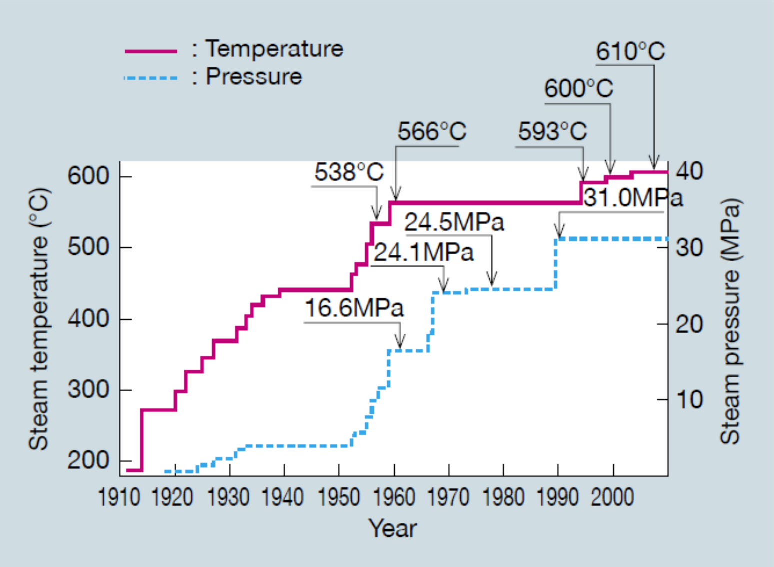
Hydro

Nuclear

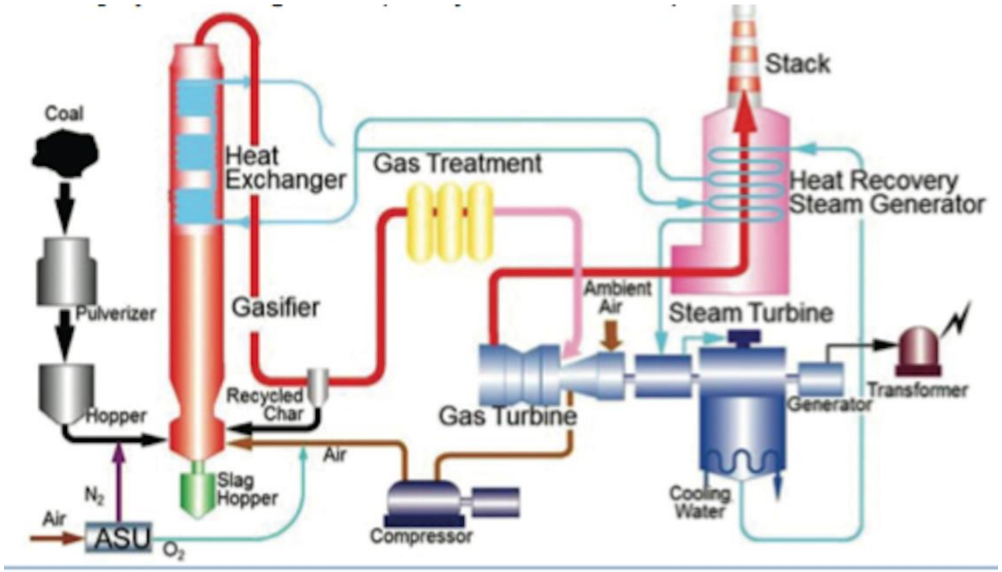
# Coal and Natural gas

- Ultra super critical (USC) thermal power plants with conditions of 24.5 MPa × 600/600°C (HELE) - Water directly becomes steam. Operating temp is very high and therefore efficiency.
- Development of the next generation, advanced ultra super critical plant (A-USC) with temperatures at 700°C and pressure above 30 MPa. (super critical 22 MPa, 374°C steam)
- Develop materials to withstand temperatures beyond 700°C, since the ferrite steel and austenite stainless steel used in conventional USC are not suitable for 700°C temperatures.
- The development of manufactur g, and inspection is required for advanced materials
- Integrated coal Gasification C power generation technology that achieves the increased efficiency by "gasifying" the coal and then using a gas turbine and a steam turbine in a two-stage generation process.

**Coal gasification** is the process of producing syngas– a mixture consisting primarily of carbon monoxide (CO), hydrogen ($H_2$), carbon dioxide ($CO_2$), natural gas ($CH_4$) , and water vapour ($H_2O$)–from **coal** and water, air and/or oxygen




Trends of steam conditions in thermal power plants

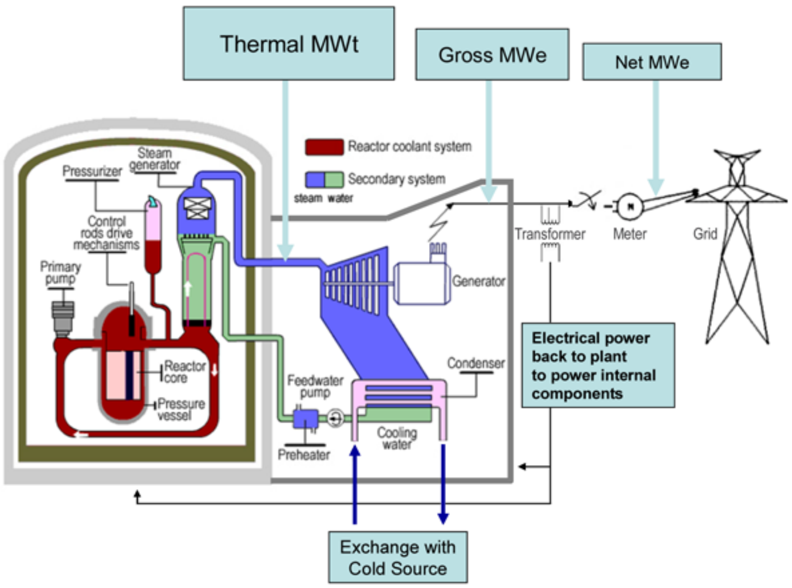



Integrated coal Gasification Combined Cycle

# Nuclear power plant

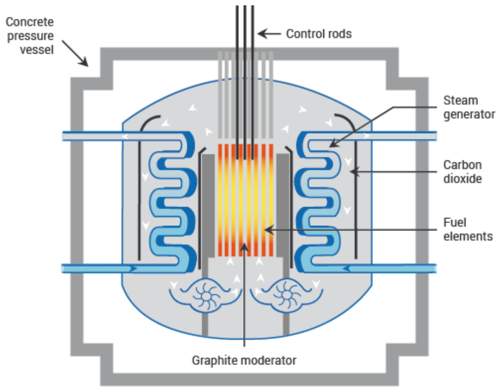
| Evolution | Feature | Example |
|---|---|---|
| Generation I Early 1950's to late 1960's | Early prototype reactors, proof-of-concept | Shippingport (1957–1982) in Pennsylvania, Dresden-1 (1960–1978) in Illinois, and Calder Hall-1 (1956–2003) in the United Kingdom. |
| Generation II (1970 - 1990) | Commercial reactors, economical and reliable Typical operational lifetime of 40 years | Pressurized water reactors (PWR), CANada Deuterium Uranium reactors (CANDU), boiling water reactors (BWR), advanced gas-cooled reactors (AGR), and Vodo-Vodyanoi Energetichesky Reactors (VVER).{LWR} |
| Generation III (1990 - 2010) | Gen II reactors with evolutionary, state-of-the-art design improvements. Areas of fuel technology, thermal efficiency, modularized construction, safety systems | Advanced Boiling Water Reactor (ABWR), VVER-1200/392M Reactor, ACR-1000, European Pressurized Reactor (EPR), Advanced PWR (APWR), AP 1000, WWER 1000 |
| Generation IV | Innovative design, high temperature, economical hydrogen gas production, thermal energy off-taking, water desalination and advanced actinide Management | High temperature water-, gas-, and liquid salt–based pebble bed thermal and epithermal reactors |

Evolution of Nuclear power reactors

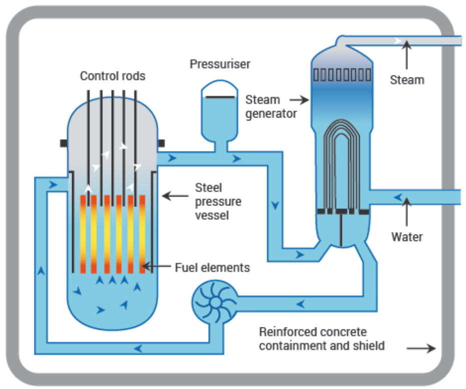



Flow diagram of nuclear power plant

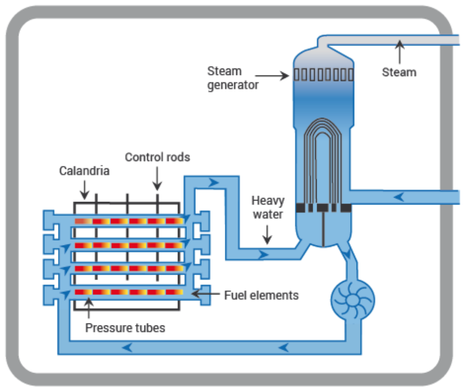
An Advanced Gas-cooled Reactor (AGR)




A Pressurized Water Reactor (PWR)




A Pressurized Heavy Water Reactor (PHWR/Candu)

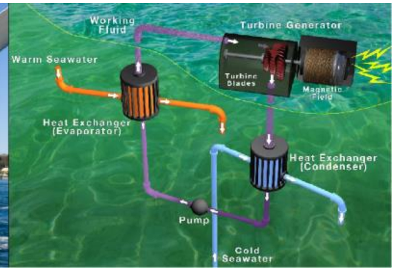



FBR (Fast Breeder Reactor) Pu-239 as fuel, Th-232 blanket is also there to capture neutron and generate U-233

AHWR - To use Thorium based fuel instead of plutonium, Next Gen Breeder reactor – U 233 as fuel

# Renewable Energy

- Solar Photo voltaic
- Concentrating solar power
- Solar heating




Solar

- Waves
- Tidal range
- Tidal current
- Ocean current
- Ocean thermal
- Salinity gradient

Marine

Renewable Energy

Wind

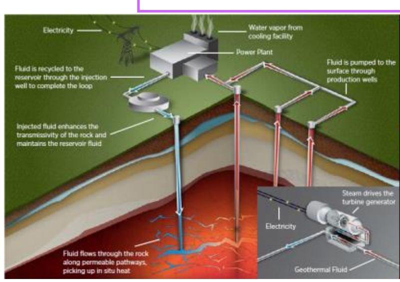
- On shore
- Off shore

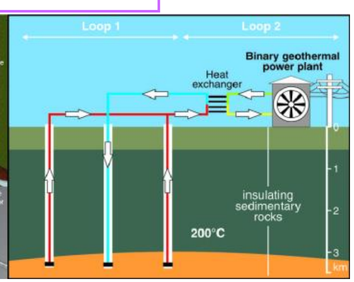
Geothermal

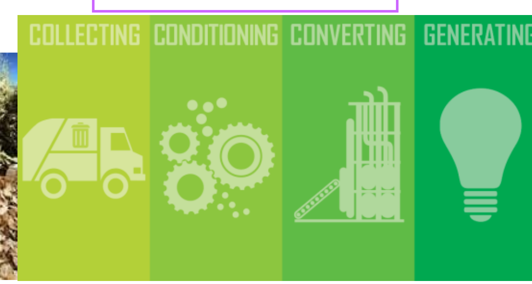
Bio Energy

- Convective system
- Conductive system
- Deep aquifer system

- Bio energy for electricity and heat
- Bio fuel



# Tesla Power bank 100 MWh

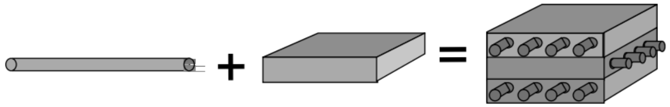
- Power bank of 100 MW / 129 MWh capacity
- It is connected to a big wind farm
- It is deployed in southern Australia and it was built in 100 days
- Battery technology is also advancing with Li-ion
- Power walls and Solar panels for housing infrastructure

# Materials

- Next generation alloys
- Nano-materials
- Composites

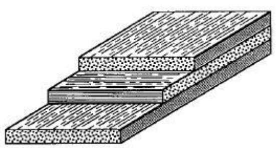
# Composite materials

- A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone.

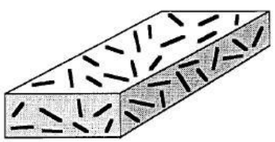


| Fiber/Filament Reinforcement | Matrix | Composite |
| --- | --- | --- |
| • High strength<br>• High stiffness<br>• Low density | • Good shear properties<br>• Low density | • High strength<br>• High stiffness<br>• Good shear properties<br>• Low density |

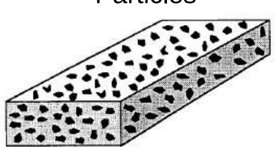
Continuous fibers



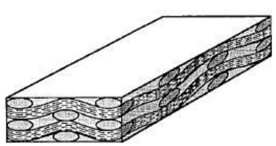
Dis-continuous fibers / Wishkers



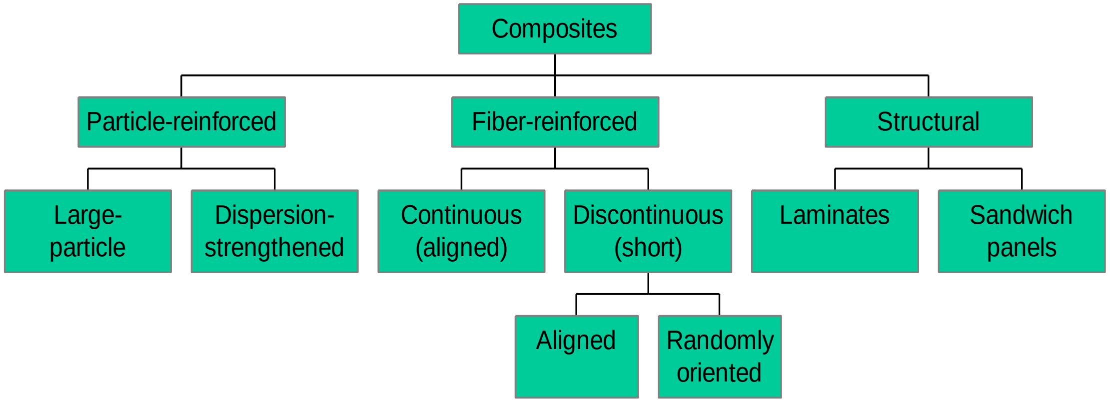
Particles



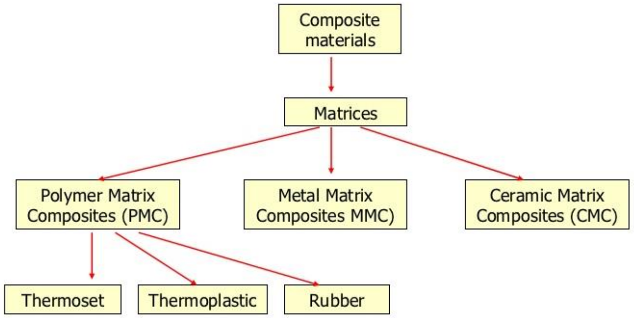
Laminated



## Classification based on fibers

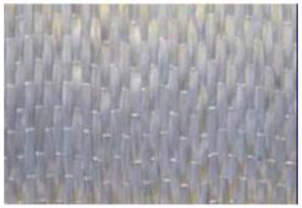



## Classification based on matrices

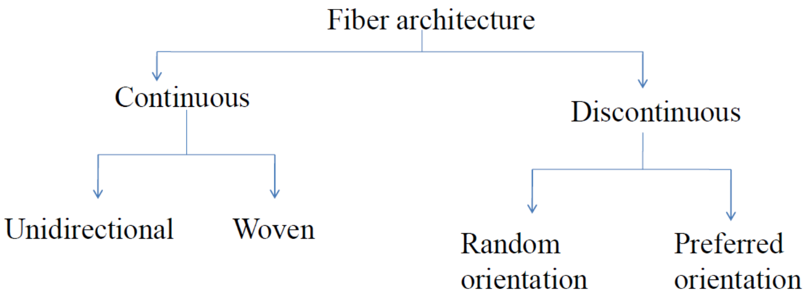


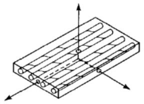

PMC: Carbon fiber reinforced polymers
MMC: Aluminum reinforced with Silicon Carbide particulate
CMC: SiC wishkers in $Al_2O_3$

# Fibers for structural application

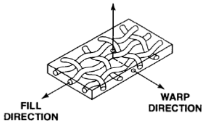


| Glass fiber | Carbon fiber | Aramid fiber |
|---|---|---|
| Low Stiffness | High Stiffness | Medium Stiffness |
| Medium Strength | High Strength | Medium Strength |
| Low cost | High cost | Medium cost |
| | Alkali resistant | Excellent ductility, toughness and impact resistance |



LAMINA WITH UNIDIRECTIONAL FIBERS

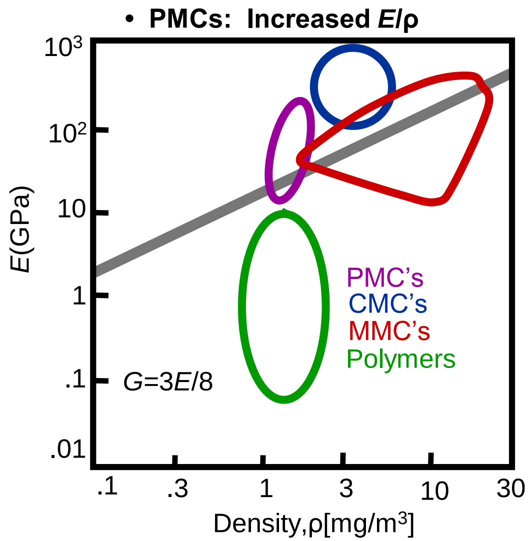



LAMINA WITH WOVEN FIBERS

Selection based on strength and stiffness, requirements cost and availability

Courtesy: Google images

# Advantages of composite materials




- High Strength to weight ratio
- High Stiffness to weight ratio
- Improved Fatigue tolerance
- Corrosion resistance
- Tailored mechanical properties
- Low thermal expansion

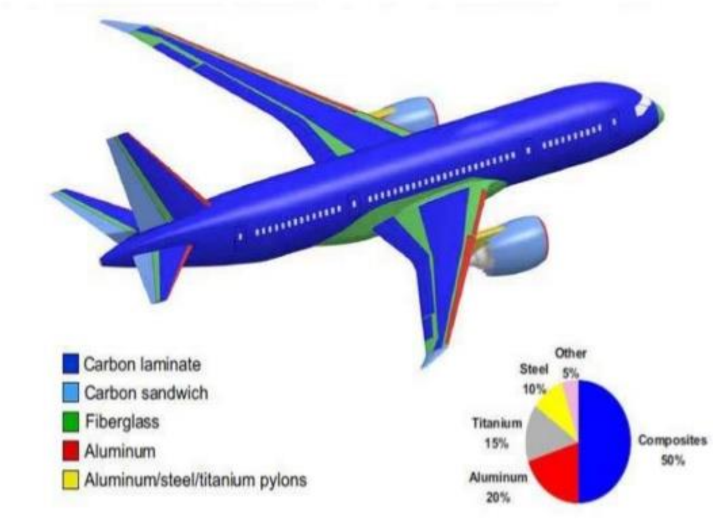
## Applications of composite material

- Aerospace
- Automotive
- Missile technology
- Marine structures
- Sporting goods
- Construction materials

## How we use composite material ?

| Boeing 777 | Boeing Dreamliner |
|---|---|
| Launched in 2000 | Launched in 2007 |
| 11 % Composites | 50% Composites |
| 70% Aluminum | 20% Aluminum |
| 7% Titanium | 15% Titanium |
| 11% Steel | 10% Steel |
| 1% Other | 5% Other |

20% more fuel consumption efficiency,
35000 lb reduction in weight



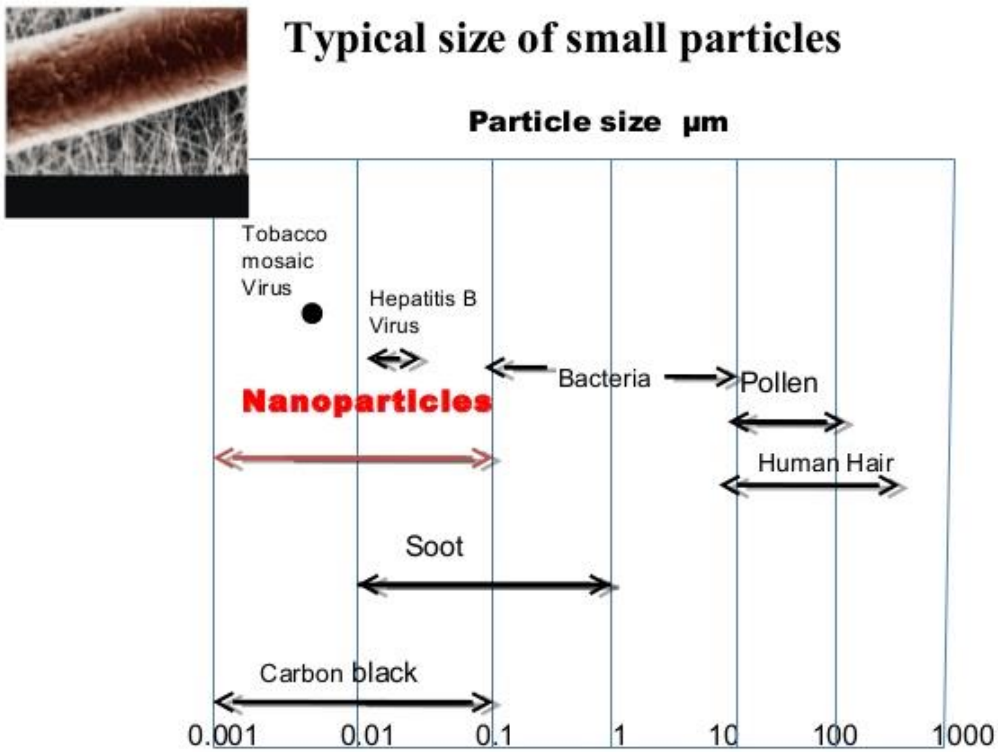

### Limitation

- Costly
- Low production rate
- Brittle by nature
- Not for high temperature ambience
- Mechanics is still evolving with respect to damage

Courtesy: Google images

# Nano materials

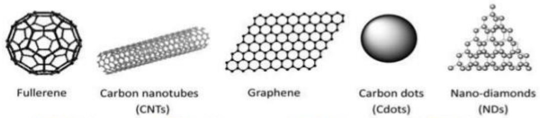
- Nano-materials are the materials containing nano crystals, i.e. their grain size is in the range of 1 to 100 nm range.
- They play a vital role in the recently developed science and technology.
- It might be a metal, alloy, intermetallic or ceramics




Courtesy: Google images

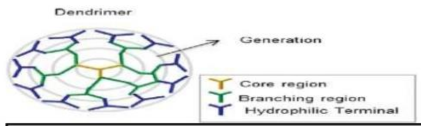
# Types of nanomaterials

- Carbon based

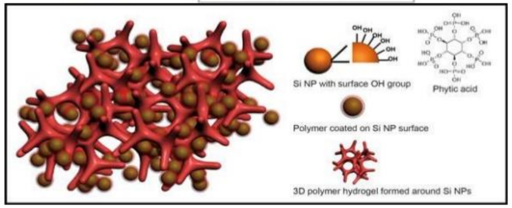



- Metal based


- Dendrimers




- Composites




## Surface Effects

- As a particle decreases in size, a greater proportion of atoms are found at the surface compared to those inside. For example, a particle of
- Size-30 nm-> 5% of its atoms on its surface
- Size-10 nm->20% of its atoms on its surface
- Size-3 nm-> 50% of its atoms on its surface
- Nanoparticals are more reactive than large particles (Catalyst)

Potential **applications** of **quantum dots** include single-electron transistors, solar cells, LEDs, lasers, single-photon sources, second-harmonic generation, **quantum** computing, and medical imaging.

## Quantum Effects

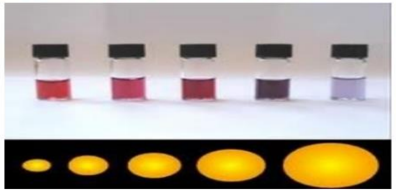
Quantum confinement

The quantum confinement effect can be observed once the diameter of the particle is of the same magnitude as the wavelength of the electron Wave function.

Quantum confinement is responsible for the increase of energy difference between energy states and band gap. A phenomenon tightly related with the optical and electronic properties of the materials.

When materials are this small, their electronic and optical properties deviate substantially from those of bulk materials.(GOLD)

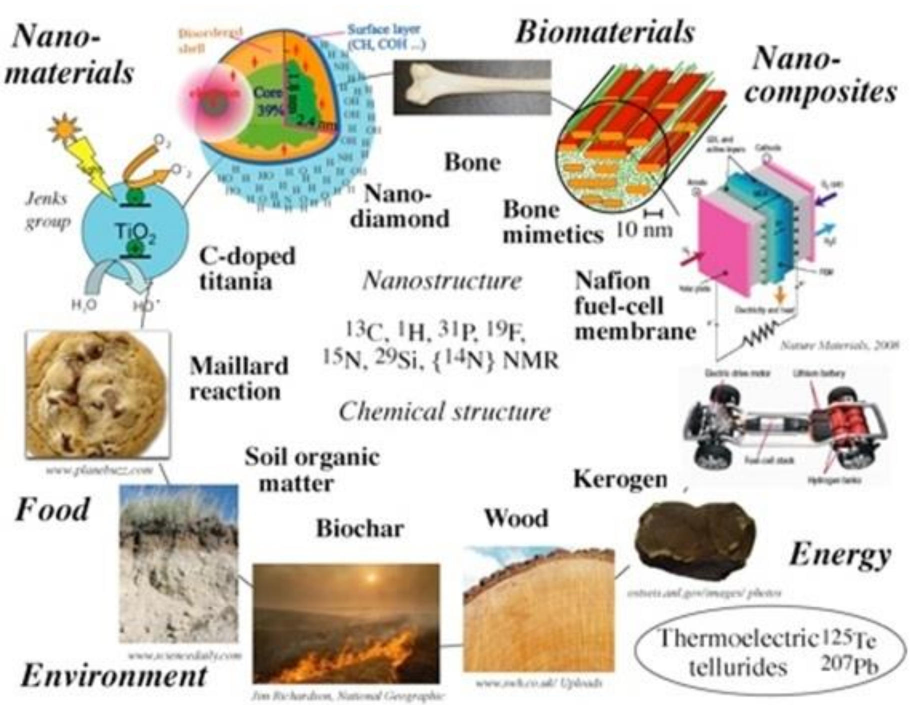
Exhibit Quantum dot capability



# Properties of nano-materials

- Nano-materials have high strength, hardness, formability and toughness.
- These materials exhibit super plasticity even at lower temperatures.
- Size of grains controls the electrical, optical, chemical and magnetic properties.
- The melting point of nanomaterials gets reduced by reducing the size of the grain size.

# Applications of nano-materials




Courtesy: Google images

# Next generation alloys

## Lithium Aluminium Alloys – The new generation aerospace alloys

Applications

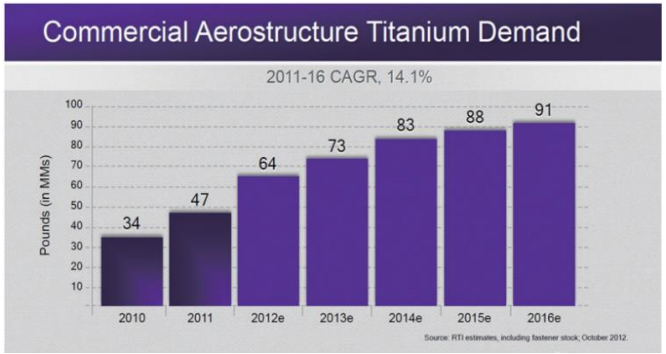
- Aircraft parts such as leading and trailing edges, access covers, seat tracks and wing skins.
- Military Applications: - Certain types of military aircrafts parts like main wing box, center fuselage, control surfaces are made by Al-Li alloys. Al-Li alloys are used as substitute for conventional Al alloys in helicopters, rockets and satellite systems.
- Space Applications: - Of all the benefits offered, by the use of Al-Li alloys, weight savings is the most critical in space applications. Al-Li alloy is a candidate material for the cryogenic tankage of booster systems. These alloys are used in cryogenic applications for example, liquid oxygen and hydrogen fuel tanks for aerospace vehicles.

## Titanium alloys for aircraft applications

- Titanium for airframes
- Titanium for engines

| Material | Example of application |
|---|---|
| Ti-6Al-4V | Cockpit window frame, Wing box, Fastener |
| Ti-3Al-2.5V | Hydraulic pipe |
| Ti-10V-2Fe-3Al | Landing gear, Track beam |
| Ti-6Al-2Sn-4Zr-2Mo | Exhaust, Tail cone |
| Ti-15V-3Cr-3Sn-3Al | Duct |

| |
|---|
| ① Weight saving |
| ② Heat resistance |
| ③ Resistance to embrittlement at low temperature |
| ④ High corrosion resistance |
| ⑤ Low-thermal expansion |

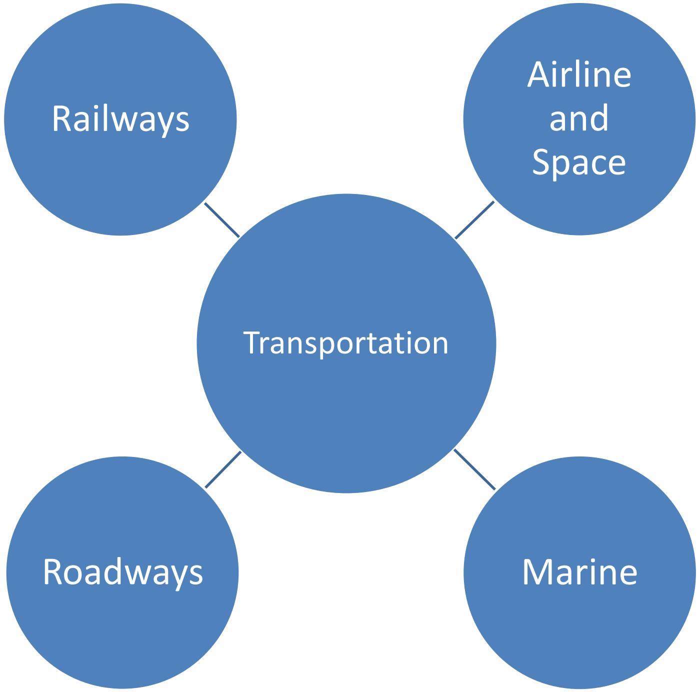



## New alloy could pave the way for next generation solar cells

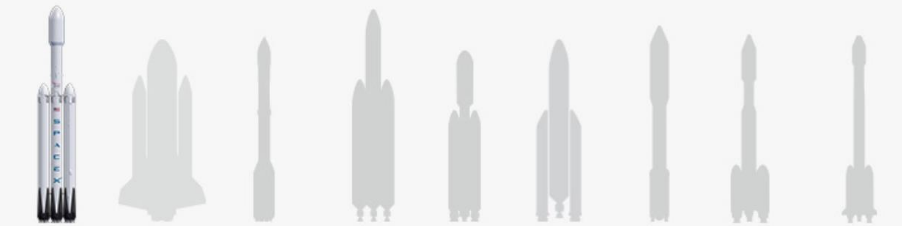
Researchers at the University of Michigan have developed a new semiconductor alloy that can capture near-infrared light in the leading edge of the visible light spectrum. This could be a major step forward the development of a new generation of solar cells called “concentrator photovoltaics”.

Courtesy: Google images

# Transportation




# Aircraft and Space craft



| LAUNCH VEHICLE | FALCON HEAVY | SPACE SHUTTLE | PROTON M | DELTA IV HEAVY | TITAN IV-B | ARIANE 5 ES | ATLAS V 551 | JAPAN H2B | CHINA LM3B |
|---|---|---|---|---|---|---|---|---|---|
| PAYLOAD TO LOW EARTH ORBIT (LEO) | 63,800 kg<br>140,660 lb | 24,000 kg<br>53,790 lb | 23,000 kg<br>50,710 lb | 22,560 kg<br>49,740 lb | 21,680 kg<br>47,800 lb | 20,000 kg<br>44,090 lb | 18,510 kg<br>40,810 lb | 16,500 kg<br>36,380 lb | 11,200 kg<br>24,690 lb |

## Airbus A380


## Stratolaunch aircraft

- Wing span of 117.358 meters from tip to tip
- Length of 72.5 meters.
- Weighs 226,800 kilograms empty
- Payloads weighing nearly 250,000 kilograms
- Air-launch platform for space launch services
- Normalizing access to low Earth orbit (LEO)

Boeing 787 Dreamliner

Long range - 14,000 Kms
Low emission
More people

India's civilian aircraft program


Falcon 9

Falcon Heavy

## Falcon Heavy details

| CORES | ENGINES |
|---|---|
| 3 | 27 |

THRUST AT SEA LEVEL
22,819 kN 5,130,000 lbf

THRUST IN VACUUM
24,681 kN 5,548,500 lbf

First stage

| ENGINE | BURN TIME |
|---|---|
| 1 | 397 sec |

THRUST IN VACUUM
934 kN 210,000 lbf

Second stage

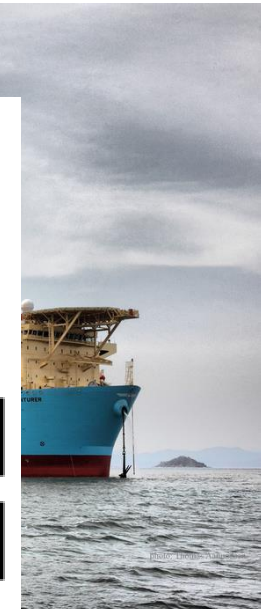
# Space Science

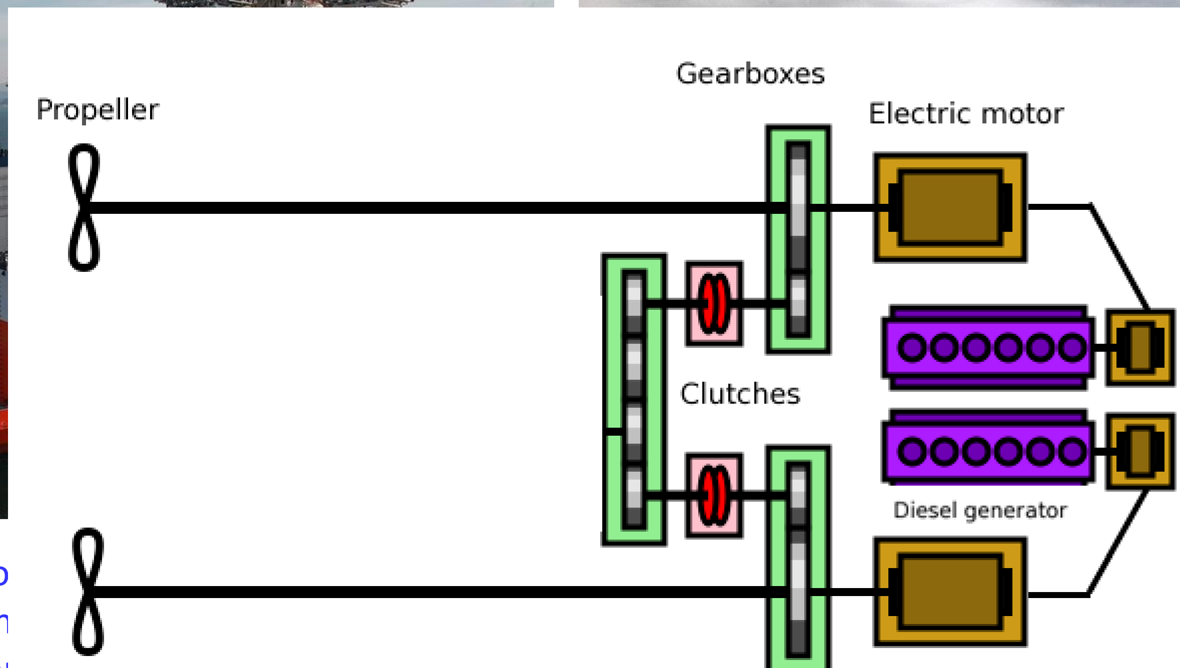
- Exploration of other planets
- Satellite & Manned mission, space station
- Scientific knowhow
- Resource mapping and retrieval
- Human settlement in exo-planets

# Marine Transport

## Heavy deck cargo ships

## Drill Ship






- The electric pro
  semi-subs and h
- Help with dyna
  and offer flexil
  space and weight restrictions
- Eliminating onboard propulsion motors and shaft lines enables more rigid aft-ship hull structure and frees more space for ballast water tanks.

ips which are
ɔeds at deep

essel to carry
out sub-water researching operations

- The drilling equipment aboard these vessels can penetrate to really greater depths and can be relocated in the high seas as the requirement necessitates

# Roadways - Hybrid electric vehicle


- BMW i8 passenger cell is made from carbon-fibre- reinforced plastic (CFRP) and an aluminium frame.

- Tesla Hybrid vehicles – Roadster – 630 Miles range, 250 mph top speed, 0- 60 mph 1.9s,

# High Speed Rail System

Bullet Train

Magnetic Levitation

- Traction switching
- Traction
- Safety
- Light weight bogies
- Control
- Braking System
- Rails

# Hyperloop System

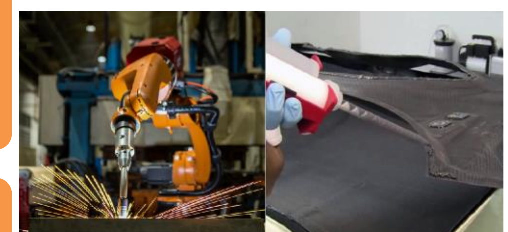

In India two corridors are considered

. Mumbai - Chennai – Total travel time - 63 minutes – 1102 km
. Bengaluru – Chennai – Total Travel time – 18 minutes – 285 km

Here a pod travels in a vacuum tunnel over the entire length
Proof of concept has been demonstrated

# Manufacturing

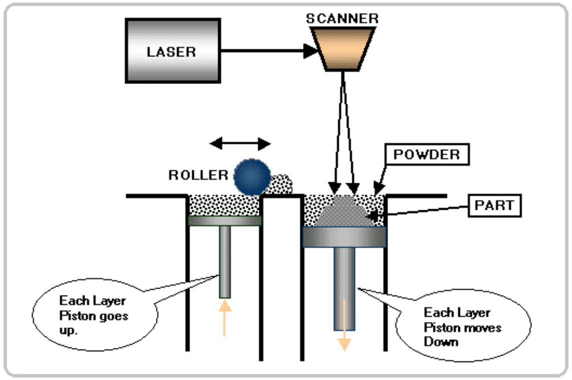
- Manufacturing Process
  - Processing operations
    - Shaping processes
    - Surface processing operation
  - Assembly operations
    - Permanent joining processes
    - Mechanical fastening



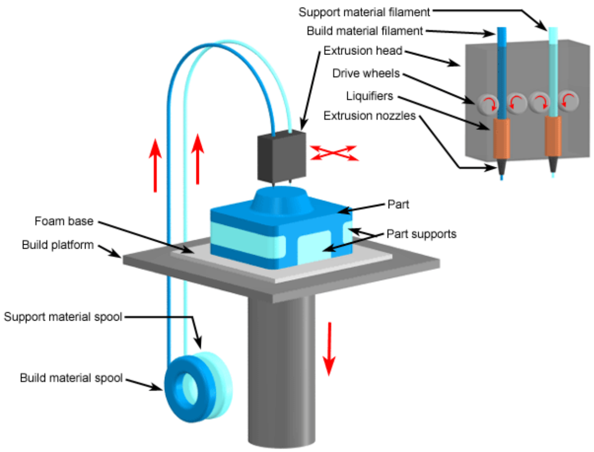
# Shaping processes

Automated system for forging process

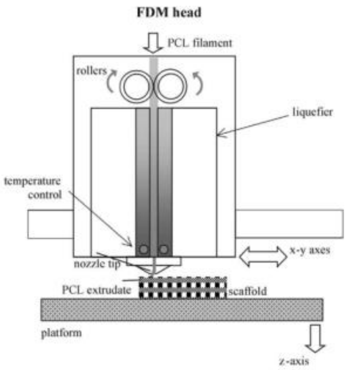
ARMS™ (Automated Robotic Melt Shop) System



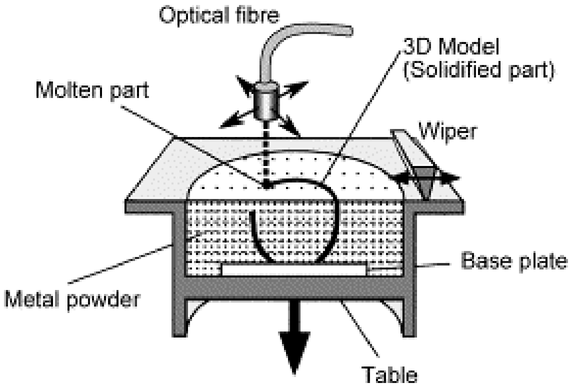

Selective laser sintering (SLS) system




3D Printing mechanism

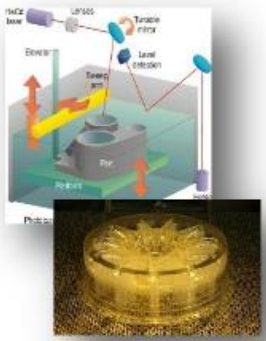
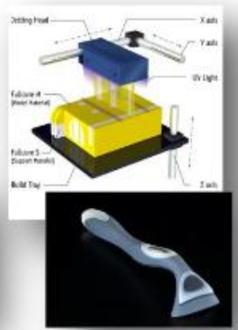
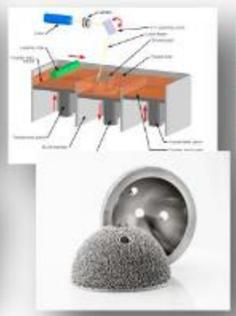



Fused Deposition Modelling (FDM) system




Selective laser melting (SLM) system

# Additive manufacturing processes

| Vat Photo-polymerization | Material Jetting | Material Extrusion | Binder Jetting | Powder Bed Fusion | Sheet Lamination | Directed Energy Deposition |
|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |
| Pre-deposited photopolymer selectively cured by light-activated cross linking of adjoining polymer Chains | Droplets are selectively deposited | Material is selectively dispensed through a nozzle/orifice in layers | Liquid bonding Agent selectively deposited to join powder materials | Thermal energy selectively fuses regions of a powder bed | Sheets of material are bonded to form an object. | Focused thermal energy fuses materials as deposited |
| *•Photopolymers* | *•"Poly-jetting"*<br>*•Photopolymers*<br>*•Wax*<br>*•Sand* | *•Plastic*<br>*•Nylon*<br>*•FDM, FFF*<br>*•Sand* | *•Metal*<br>*•Plastic*<br>*•Ceramic/Sand*<br>*•Full Color* | *LASER & EB:*<br>*•metals*<br>*$CO_2$ LASER:*<br>*•Polymers*<br>*•Fiber* | *•Metal*<br>*•Paper*<br>*•Wood*<br>*•Plastics* | *•Wire & Powder*<br>*•LASER & EB*<br>*•For feature addition/repair* |

**Metal Parts In-Directly** (Vat Photo-polymerization, Material Jetting, Material Extrusion)

**Metal Parts Directly** (Binder Jetting, Powder Bed Fusion, Sheet Lamination, Directed Energy Deposition)

Seven additive manufacturing processes according to ASTM Committee F42 on Additive Manufacturing. Source: Boeing/ASTM

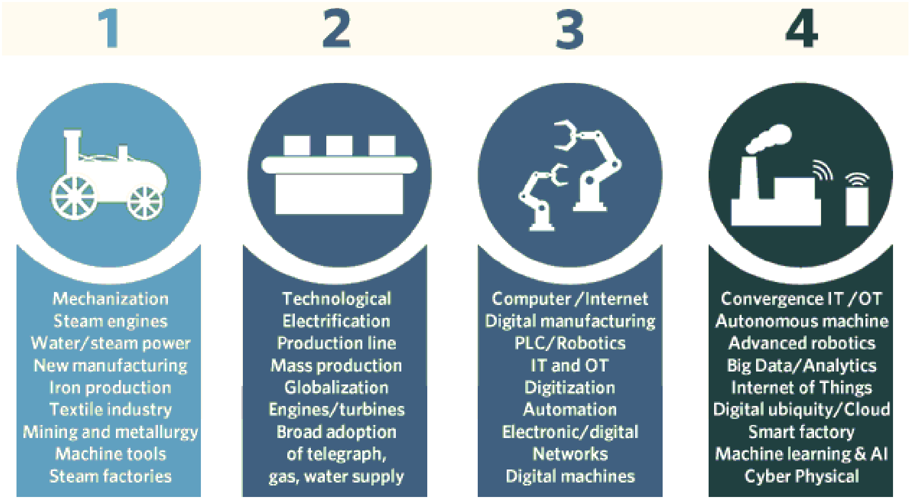
# Machine tools

- CNC Machine Tools eliminate the flexibility that is significant for robots.
- Important to combine the flexibility and envelope of the robots with the accuracy and stiffness of traditional Machine Tools
- Parallel Kinematics Machines (PKM) offers motion in X, Y and Z axis by three or more parallel axes that gives an outstanding stiffness and accuracy maintaining flexibility and envelope.
- The reach of the tool in PKM is almost spherical, hence it offers flexibility in manufacturing a complex component.
- PKM has the following advantages over the traditional machine tool technology:
  - ➢ Reduced Fixturing
  - ➢ Reduced Job Handling
  - ➢ Reduced set-up time
  - ➢ Enhanced Production

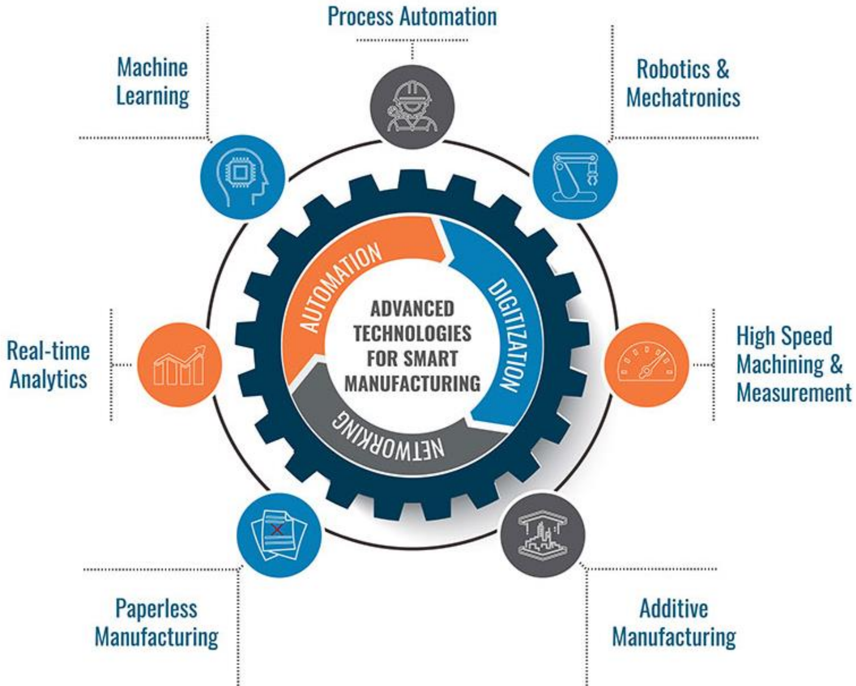
Tricept T605 by PKMtricept

EXECON parallel machine tool

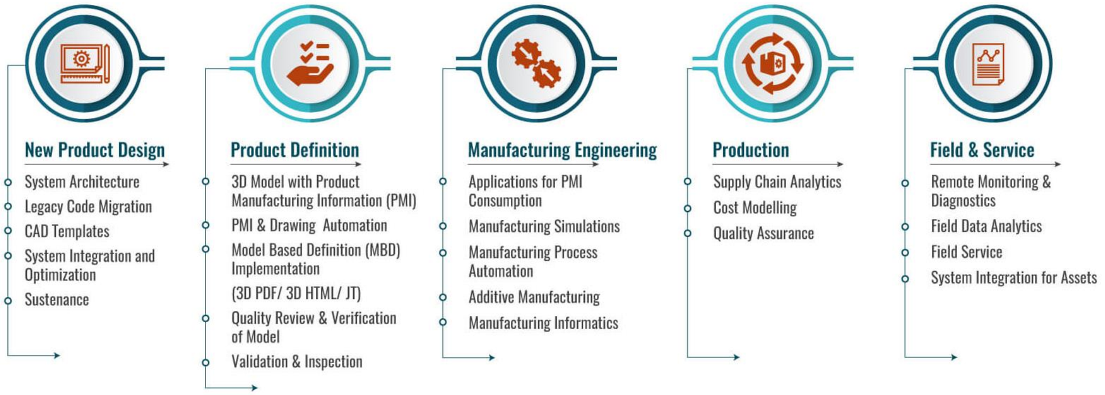
# Industry 4.0: the fourth industrial revolution




Stages of industrial revolution




Smart manufacturing




Application of digitisation at various stages of manufacturing

Digital Twin

# Defence

# Armoured vehicles

## Indigenously developed MBT Arjun MK II

Indian Institute of Technology Hyderabad


| | | | |
|---|---|---|---|
| **Armament** | One 120mm, one 12.7mm remote weapon station, one 7.62mm coaxial machine gun | **Armor** | Protection against small arms firing and shell splinters. Explosive reactive armor and KANCHAN armour. |
| **Country users** | Project | **Combat Weight** | 68,000 kg |
| **Designer Country** | India | **Speed** | 58 km/h maximum road speed |
| **Accessories** | Laser range finder, computerized fire control, auxiliary power unit, thermal night vision, laser warning and countermeasure system, GPS navigation system, NBC protection system, fume extractor, and integrated fire detection and suppression system | **Range** | 500 km |
| **Crew** | 4 | **Dimensions** | Length: 10.64 m; Width: 3.95 m; Height: 3.18 m |

Courtesy: Google images

Special features

- Automatic fire detection and suppression systems
- Nuclear, biological, chemical protection systems
- Urban survival kit that includes laser warning and an aerosol smoke grenade system
- A panoramic sight with night vision
- Some MBT's have reactive armours – ERA, NERA, Kanchan armour
- Arjun MBT 1A is in production 108 tanks – 3rd Gen – 68 tonnes
- Armour piercing fin stabilised discharging Sabot
- MTU 1400 Hp Engine - liquid cooled turbocharged diesel
- FCS & Transmission system 4F & 2R, HP suspension

# Future of armorued vehicle technology

- Vehicle protection
  - ✓ V-shaped Hull - deflects the force of a blast
  - ✓ Use of Composites – High strength Less weight (vehicle can carry more fuel, ammunition and troops)
  - ✓ Slat armour - Less detonation
  - ✓ Chobham armour – composite by nature
- Systems and sensors
  - ✓ Communications- real-time data on the combat
  - ✓ Optics – High strength Less weight (night-vision equipment)
- Vehicle components
  - ✓ Wheels and tyre technology - runflat technology, beadlock system
  - ✓ Hybrid engines – electric motors and a lightweight diesel engine
- Weapons
  - ✓ Remote weapon systems - Tactical Remote Turret (multiple weapon systems on one turret), co-axial machine gun and anti-tank guided missiles
  - ✓ Lasers – the directed energy weapon option (They do not require ammunition resupplies)

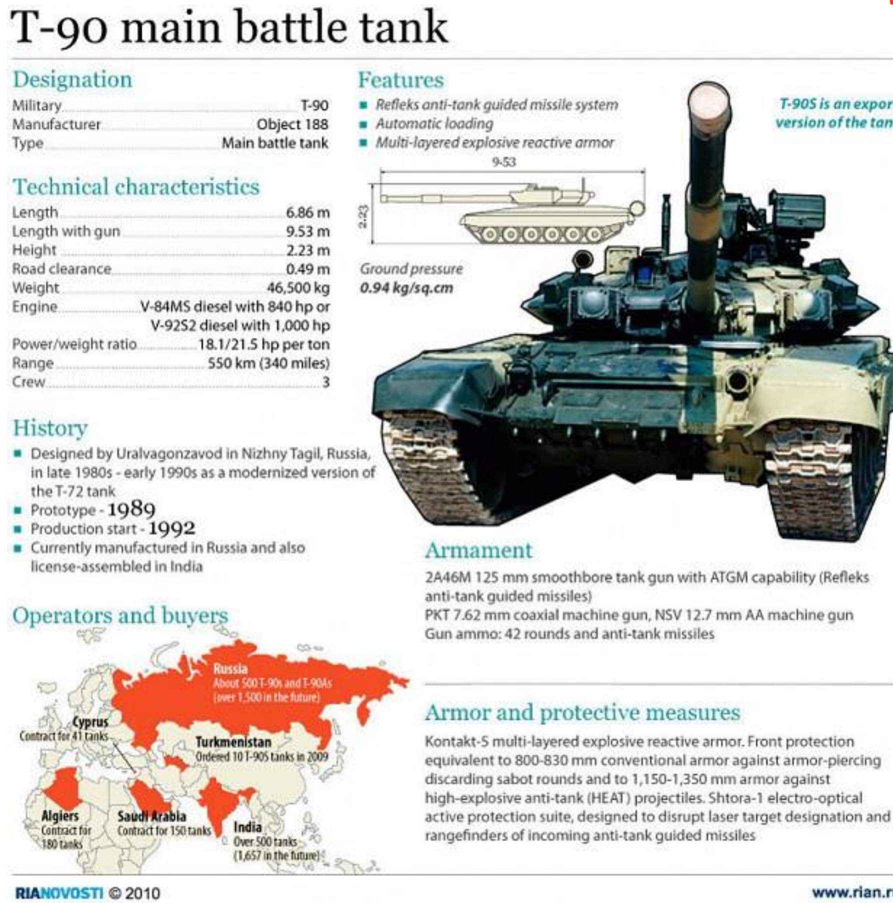
An IDF Caterpillar D9 armoured bulldozer equipped with slat armor surrounding its driver's cab.

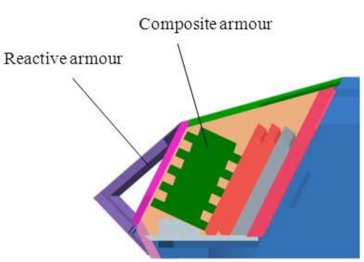
Composite materials and additive manufacturing (Modern British main battle tank with composite armor)

Courtesy: Google images

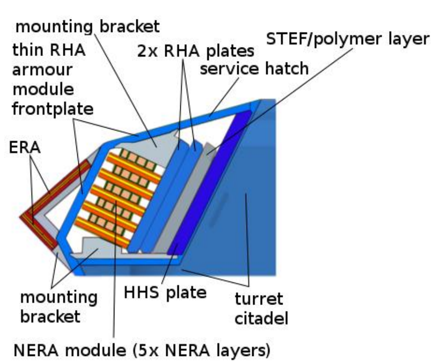
Reference link: https://www.army-technology.com/features/feature-the-future-armoured-vehicle-technology/


| PARAMETERS | ARJUN - 2 | CHALLENGER - 2 (UK) | T-90 (RUSSIA) |
|---|---|---|---|
| Weight | 65 tonnes | 62.5 tonnes | 46.5 tonnes |
| Max Speed | 58.5 km/hr | 56 km/hr | 65km/hr |
| Range | 500km | 450km | 650km |
| Engine Power | 1,500hp | 1,200hp | 1,000hp |
| Gun | 120mm rifled | 120mm rifled | 125mm smooth bore |
| Crew | 4 | 4 | 3 |




Turret front protection




Courtesy: Google images

T-14 Armata, Russia


PL-01, Poland

Its turret is unmanned and capable of being operated by three crew members from within the hull. It features a 125mm tank gun and Russian armor-piercing and high-explosive shells as well. Additional weaponry may include a coaxial 30mm autocannon and PKT machine gun.

It can be carried on an airplane and dropped into combat. What makes the PL-01 so different is its active infrared camouflage system. The surface of the tank can be heated or cooled so that heat-seeking missiles and infrared sensors used by infantry and tank-searching helicopters can't find it. The muzzle even features a suppressor and a radar-deflecting surface.

Need for light tank tank



Courtesy: Google images

# Missiles

## Surface to Surface missiles

## Prithvi series missiles

| Name | Type | Stage(s) | Range | Payload |
|---|---|---|---|---|
| Prithvi-I (SS-150) | SRBM | One | 150 km | 1000 kg |
| Prithvi-II (SS-250) | SRBM | Two | 250 km – 350 km | 500 kg – 1000 kg |
| Prithvi-III (SS-350) | SRBM | Two | 350 km – 600 km | 250 kg – 500 kg |


## Agni series missiles

| Name | Type | Stage(s) | Range | Payload |
|---|---|---|---|---|
| Agni-I | MRBM | One | 700 km – 1,200 km | 1 Tonne |
| Agni-II | IRBM | Two | 2,000 km – 2,500 km | 1 Tonne |
| Agni-III | IRBM | Two | 3,000 km – 5,000 km | 2.5 Tonne |
| Agni-IV | IRBM | Two | 2,500 km – 3,700 km | 2 Tonee |
| Agni-V | ICBM | Three | 5,000 km – 8,000 km | 1.5 Tonee |
| *Agni-VI | ICBM | Three | 10,000 km – 12,000 km | 3 Tonne |

Note:
SRBM-Short range ballistic missile
MRBM-Medium range ballistic missile
IRBM-Intermediate range ballistic missile
ICBM-Intercontinental ballistic missile
* Under development

Courtesy: Google images

Courtesy: Google images

# Submarine launched ballistic missiles

## K-series missiles

| Type | Type | Range | Warhead |
|---|---|---|---|
| K-15 | SRBM | 750 km | 1 Tonne |
| K-4 | IRBM | 3,500–5,000 km | 1 Tonne– 2.5 tonnes |
| *K-5 | ICBM | 6,000 km | 1 Tonne |

# Surface to air ballistic missiles

| Type | Type | Range |
|---|---|---|
| Akash Missile | Medium-range surface-to-air missile | 30-35 km |
| Barak 8 | Long Range Surface to Air Missile | 100 km |

# Anti-ballistic missiles

| Type | Type | Range |
|---|---|---|
| Prithvi Air Defence (PAD) | Exo-atmospheric Anti-ballistic missile | Altitude- 80km |
| Advanced Air Defence (AAD) | Endo-atmospheric Anti-ballistic missile | Altitude- 30km |
| Prithvi Defence Vehicle (PDV) | Exo-atmospheric Anti-ballistic missile | Altitude-120km |

# Air to air ballistic missiles

| Type | Type | Range |
|---|---|---|
| Astra Missile | Short range air-to-air missile | 60-80 km |
| K-100 | Medium range air-to-air missile | 300-400 km |

Note:
SRBM-Short range ballistic missile
MRBM-Medium range ballistic missile
IRBM-Intermediate range ballistic missile
ICBM-Intercontinental ballistic missile
* Under development

# Cruise missiles

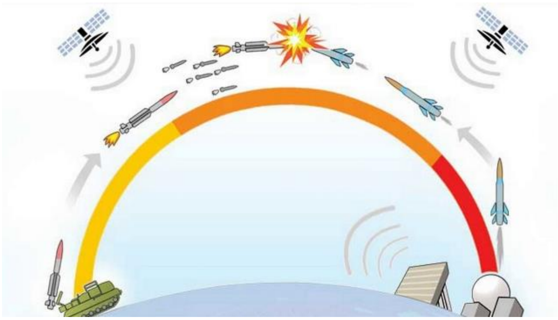
| Type | Type | Range |
|---|---|---|
| Nirbhay | Subsonic cruise missile(Ship, submarine, aircraft and land) | 1,000 -1500 km |
| BrahMos | Supersonic cruise missile(Ship, submarine, aircraft and land) | 290 km |
| BrahMos II | Hypersonic cruise missile(Ship, submarine, aircraft and land) | 300km |

# List of Indian ballistic missiles

- Short Range Ballistic Missiles (SRBM)
  - ✓ Agni-I
  - ✓ Prithvi-I
  - ✓ Prithvi-II
  - ✓ Prithvi-III
  - ✓ Dhanush
- Medium Range Ballistic Missiles (MRBM)
  - ✓ Agni-II
- Intermediate Range Ballistic Missiles (IRBM)
  - ✓ Agni-III
- Intercontinental Ballistic Missiles (ICBM)
  - ✓ Agni-IV
  - ✓ Agni-V
  - ✓ Agni III SL
  - ✓ Surya-I
  - ✓ Surya-II
- Surface to surface Ballistic Missiles (SSBM)
  - ✓ Shaurya
- Submarine Launched Ballistic Missiles (SLBM)
  - ✓ Sagarika
- Anti-submarine Missiles (ASM)
  - ✓ Popeye
- Surface to Air Missiles (SAM)
  - ✓ Akash
- Cruise Missile
  - ✓ BrahMos-I (Supersonic)
  - ✓ BrahMos-II (Hypersonic)
  - ✓ Nirbhay (Subsonic)
  - ✓ P-270 Moskit (Supersonic)

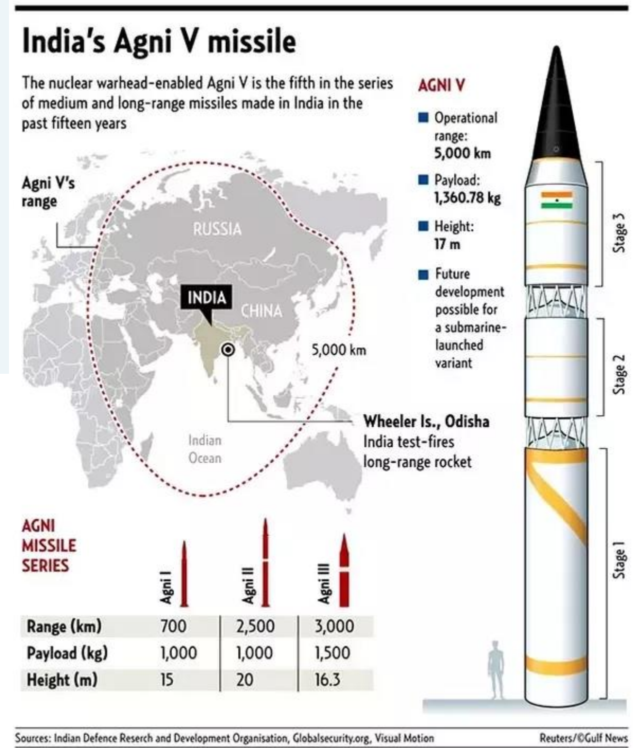

From left: Agni- IIITD, Agni- IIIA, Agni- IIIB, Agni- IIIC, Agni- IIISL

Anti-ballistic missile technology



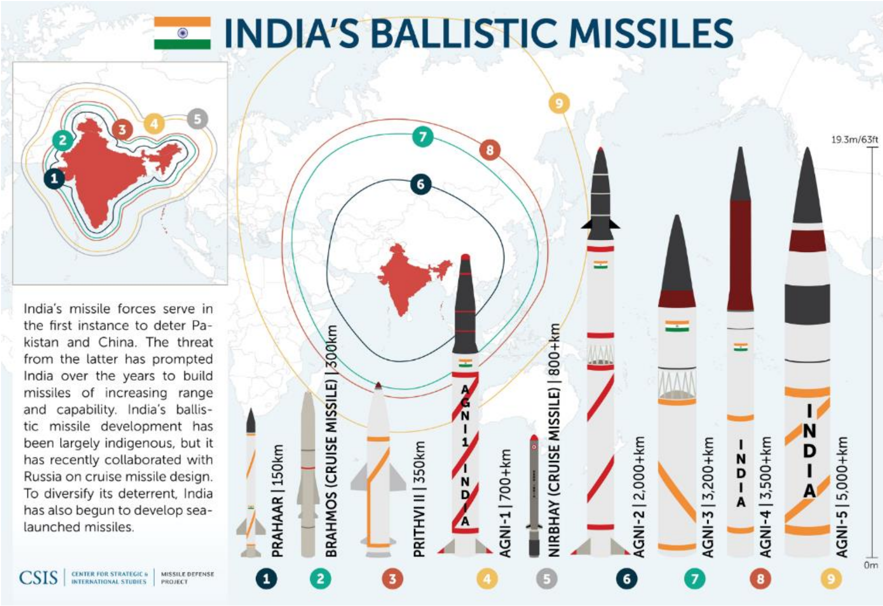
| Regime | Subsonic | Transonic | Sonic | Supersonic | Hypersonic | Hypervelocity |
|---|---|---|---|---|---|---|
| Mach | <0.8 | 0.8–1.2 | 1.0 | 1.2–5.0 | 5.0–10.0 | >10.0 |

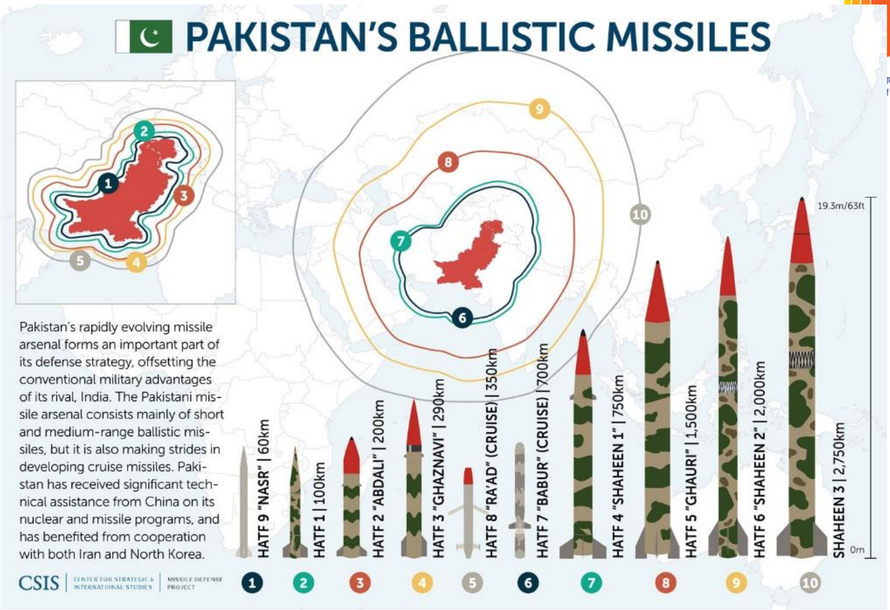
Courtesy: Google images

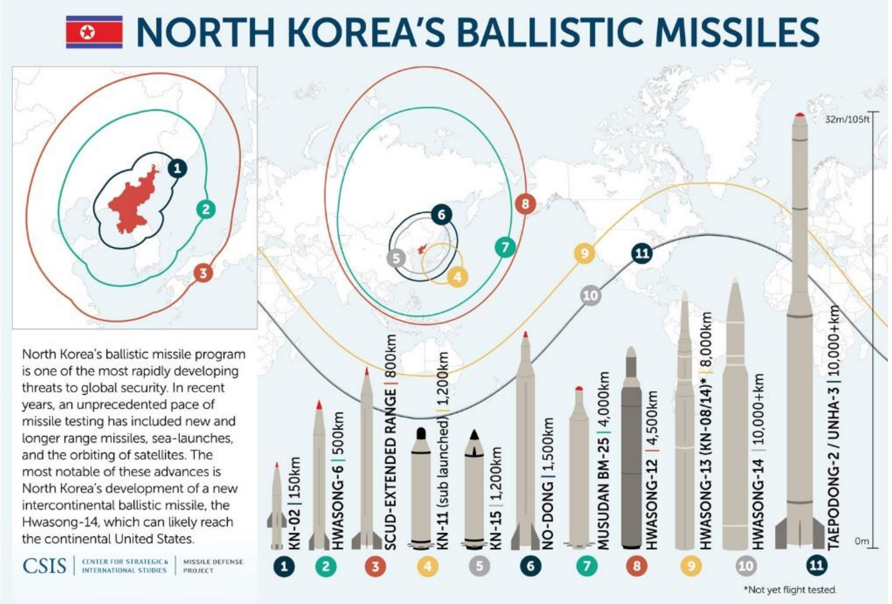

| | Agni I | Agni II | Agni III |
|---|---|---|---|
| Range (km) | 700 | 2,500 | 3,000 |
| Payload (kg) | 1,000 | 1,000 | 1,500 |
| Height (m) | 15 | 20 | 16.3 |

Courtesy: Google images





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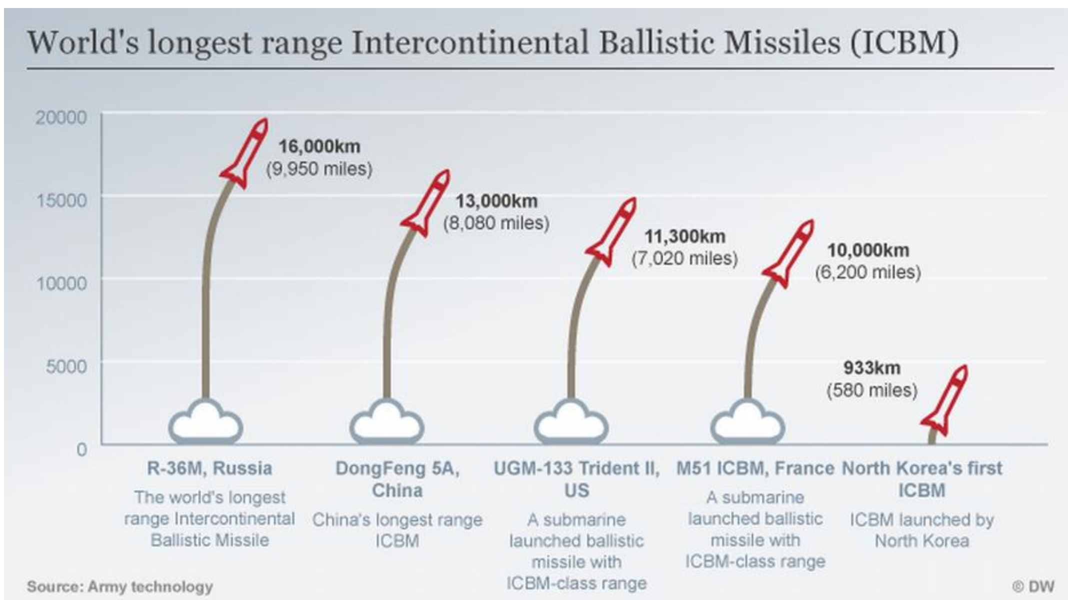


Courtesy: Google images

# Indian Fighter Aircrafts

### HF-24 Marut

| | |
|---|---|
| **Role** | Fighter-bomber |
| **National origin** | India |
| **Manufacturer** | Hindustan Aeronautics Limited |
| **Designer** | Kurt Tank |
| **First flight** | 17 June 1961 |
| **Introduction** | 1 April 1967 |
| **Retired** | 1990 |
| **Primary user** | Indian Air Force |
| **Number built** | 147[1] |

### Lakshya PTA

| | |
|---|---|
| **Role** | Pilotless Target Aircraft |
| **Manufacturer** | HAL |
| **Designer** | DRDO (ADE) |
| **First flight** | 1985 |
| **Introduction** | 9 November 2000 |
| **Status** | Active |
| **Primary user** | Indian Army<br>Indian Air Force<br>Indian Navy |
| **Produced** | 30 |
| **Unit cost** | ₹29,375,000 (US$450,000)[1] |

### Su-30MKI

An Indian Air Force Su-30MKI

| | |
|---|---|
| **Role** | Multirole air superiority fighter |
| **National origin** | Russia / India |
| **Manufacturer** | Hindustan Aeronautics Limited |
| **Designer** | Sukhoi |
| **First flight** | Su-30MK: 1 July 1997<br>Su-30MKI: 2000 |
| **Introduction** | 27 September 2002 |
| **Status** | In service |
| **Primary user** | Indian Air Force |
| **Produced** | Su-30MKI: 2000–present |
| **Number built** | 240 as of October 2017[1] |
| **Unit cost** | ₹358 crore (US$55 million) in 2014[2] |
| **Developed from** | Sukhoi Su-30 |
| **Variants** | Sukhoi Su-30MKM |

### Tejas

| | |
|---|---|
| **Role** | Multirole light fighter |
| **National origin** | India |
| **Manufacturer** | Hindustan Aeronautics Limited (HAL) |
| **Design group** | Aeronautical Development Agency |
| **First flight** | 4 January 2001 |
| **Introduction** | 17 January 2015[1] |
| **Status** | In service[2] |
| **Primary user** | Indian Air Force |
| **Produced** | 2001–present |
| **Number built** | 24 (including prototypes as of March 2018)[3] |
| **Program cost** | ₹7,399.69 crore (US$1 billion) (LCA total in 2015)[4] |
| **Unit cost** | ₹160 crore (US$25 million) for Mark I[5][6]<br>US$40 million for Mark IA[7] |

### Advanced Medium Combat Aircraft

| | |
|---|---|
| **Role** | Stealth multirole fighter |
| **National origin** | India |
| **Manufacturer** | Hindustan Aeronautics Limited |
| **Designer** | Aeronautical Development Agency<br>Defence Research and Development Organisation |
| **Status** | Under development |
| **Primary users** | Indian Air Force<br>Indian Navy |


Courtesy: Google images & ADA

# Indigenously developed fighter aircrafts

Tejas LCA

| | |
|---|---|
| **Role** | Multirole light fighter |
| **National origin** | India |
| **Manufacturer** | Hindustan Aeronautics Limited (HAL) |
| **Design group** | Aeronautical Development Agency |
| **First flight** | 4 January 2001 |
| **Introduction** | 17 January 2015[1] |
| **Status** | In service[2] |
| **Primary user** | Indian Air Force |
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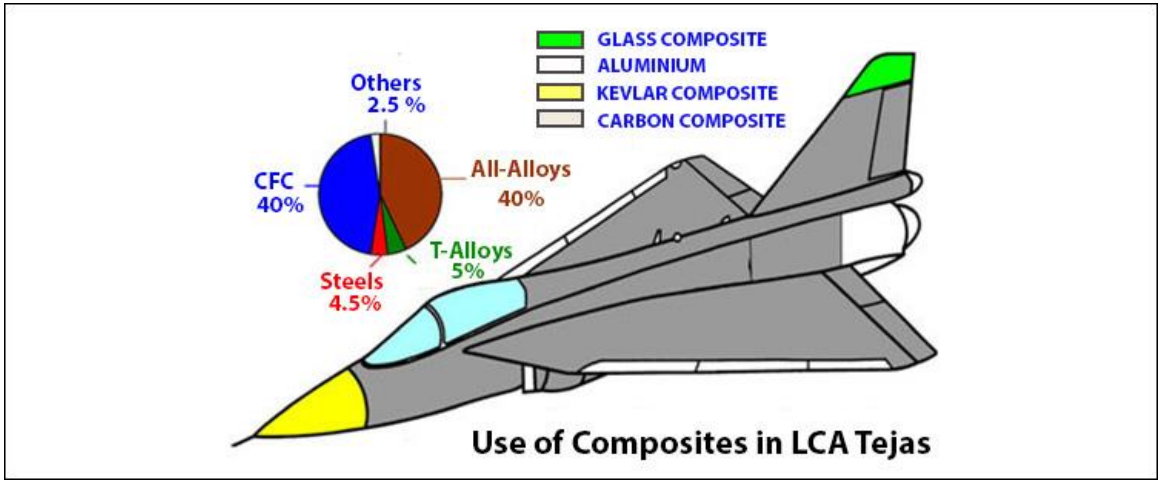


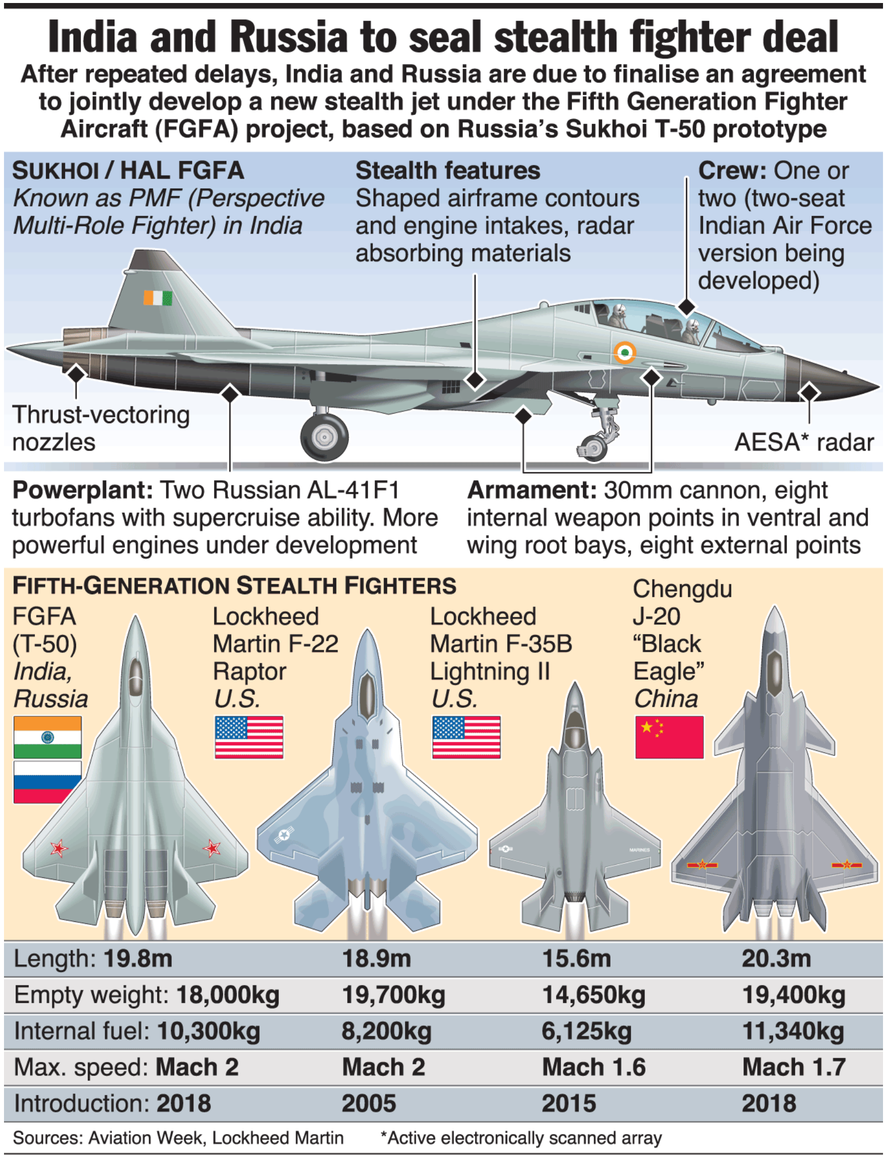

Courtesy: Google images


It is a multirole combat aircraft designed for the air superiority, ground attack, bombing, intercepting, Strike and other types of roles. It combines super cruise, stealth, *AESA radar*, maneuverability, and advanced avionics to overcome and suppress previous generation fighter aircraft along with many ground and maritime defences.

*Advanced Medium Combat Aircraft (AMCA)* is an Indian programme of a *fifth-generation fighter aircraft*. It is being developed by an aerospace industry team which consist of *Aeronautical Development Agency* as a design firm and to be manufactured by *Hindustan Aeronautics Limited (HAL)*. It is a single-seat, twin-engine, stealth supermaneuvrable all weather multirole fighter aircraft. Unofficial design work on the AMCA started in *2008* with official work started in 2011 and completed in 2014. In 2008 *Indian Navy* joined the programme for the naval variant optimized for the aircraft carriers operation. The first flight is scheduled to occur in *2023–2024*.

Courtesy: Google images

# Stealth technology



## India and Russia to seal stealth fighter deal

**After repeated delays, India and Russia are due to finalise an agreement to jointly develop a new stealth jet under the Fifth Generation Fighter Aircraft (FGFA) project, based on Russia's Sukhoi T-50 prototype**

**SUKHOI / HAL FGFA**
*Known as PMF (Perspective Multi-Role Fighter) in India*

**Stealth features** Shaped airframe contours and engine intakes, radar absorbing materials

**Crew:** One or two (two-seat Indian Air Force version being developed)

Thrust-vectoring nozzles

AESA* radar

**Powerplant:** Two Russian AL-41F1 turbofans with supercruise ability. More powerful engines under development

**Armament:** 30mm cannon, eight internal weapon points in ventral and wing root bays, eight external points

**FIFTH-GENERATION STEALTH FIGHTERS**

| FGFA (T-50) *India, Russia* | Lockheed Martin F-22 Raptor *U.S.* | Lockheed Martin F-35B Lightning II *U.S.* | Chengdu J-20 "Black Eagle" *China* |
|---|---|---|---|
| Length: **19.8m** | **18.9m** | **15.6m** | **20.3m** |
| Empty weight: **18,000kg** | **19,700kg** | **14,650kg** | **19,400kg** |
| Internal fuel: **10,300kg** | **8,200kg** | **6,125kg** | **11,340kg** |
| Max. speed: **Mach 2** | **Mach 2** | **Mach 1.6** | **Mach 1.7** |
| Introduction: **2018** | **2005** | **2015** | **2018** |

Sources: Aviation Week, Lockheed Martin *Active electronically scanned array

## UAV

Predator


Courtesy: Google images

# Warhead carriers

INS Viraat

INS Viraat is the oldest aircraft carrier in the world which was built in the British era and still serving in Indian Navy.

It has completed more than 50 years and has been in Indian Navy for more than 25 years which makes it different and special in the world.

It was expected to be decommissioning INS Viraat by 2015-16, but some upgradation made in it increased its life till 2020. As the maintenance cost of the ship was increasing, the decommissioning was later scheduled in 2016-17.

Courtesy: Google images

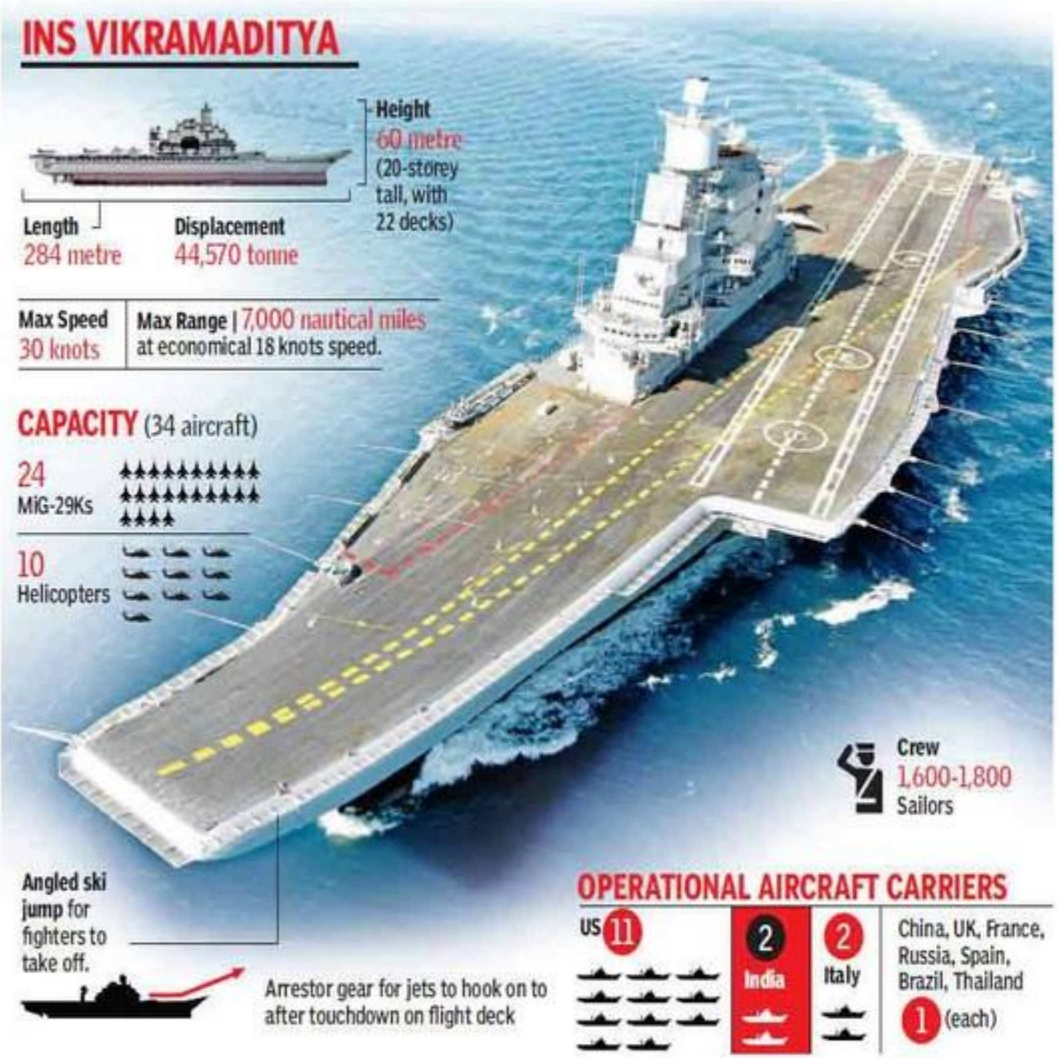

INS Vikranth



IAC-1

Courtesy: Google images

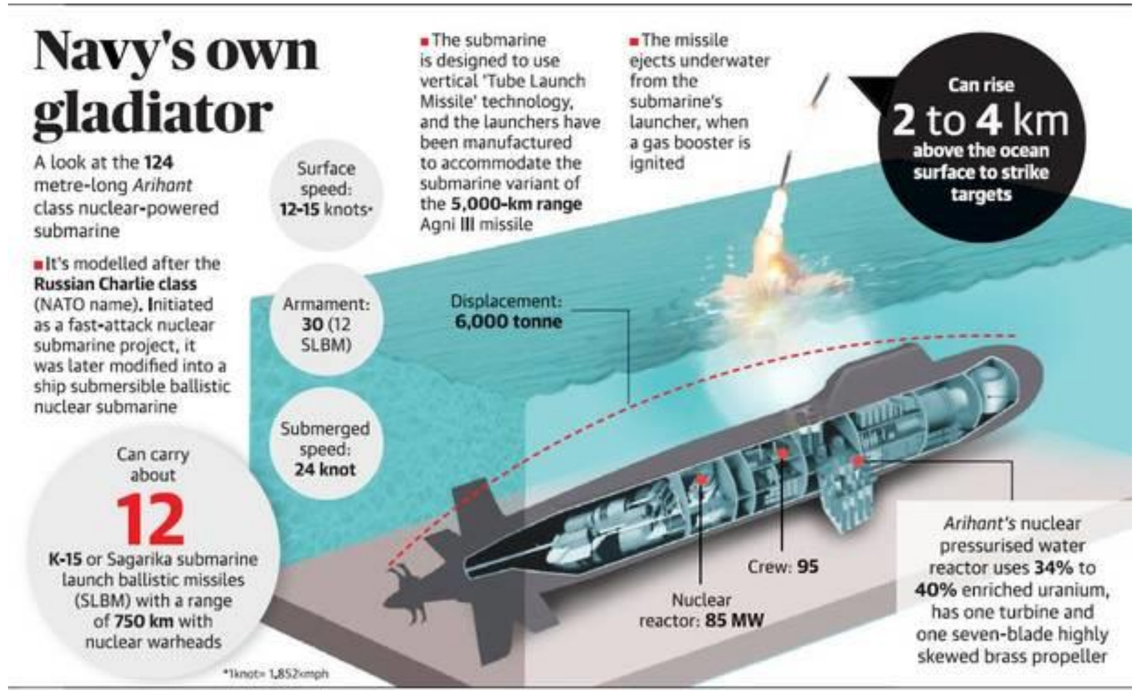
INS Vikramaditya




Courtesy: Google images

# Submarines

INS Arihant (India's first nuclear submarine)

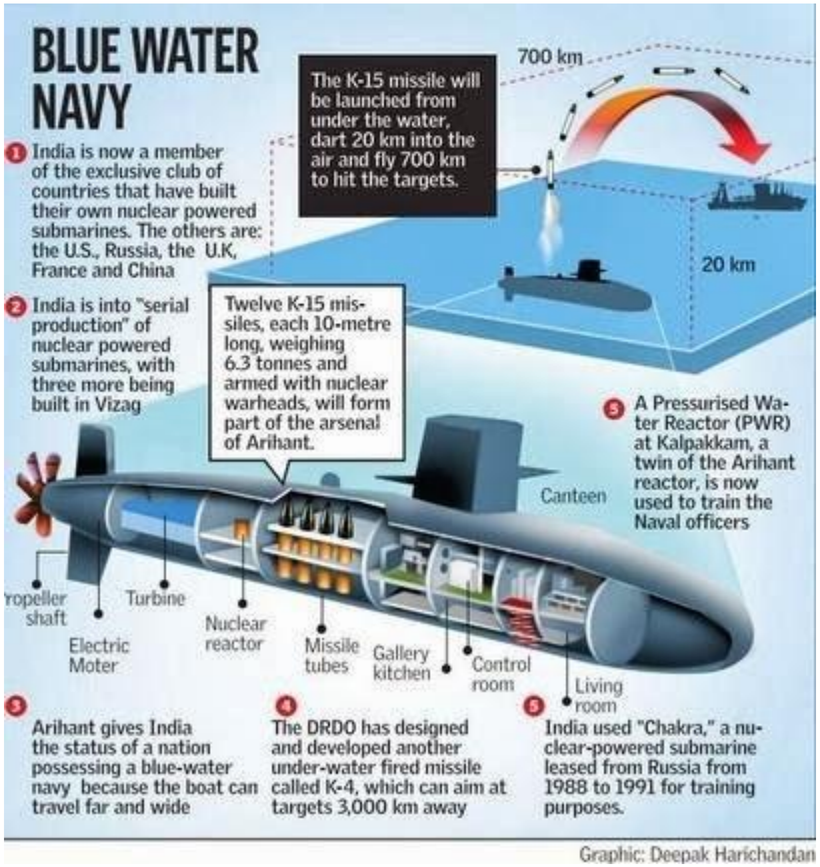



- High strength alloy steels are used
- AIP module – Battery operated propulsion using Fuel Cells

Courtesy: Google images

भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad


INS Chakra




Courtesy: Google images

# Rifles

Evolution of the modern rifle:
**Top:** Baker rifle, an early 19th-century flintlock rifle.
**Second:** Pattern 1853 Enfield, a mid 19th-century caplock rifled musket.
**Third:** Dreyse needle gun, the first standard issue military breechloading rifle.
**Fourth:** Henry rifle, the first successful lever action repeating rifle.
**Fifth:** Lebel Model 1886 rifle, a late 19th-century bolt-action rifle and the first to use smokeless powder.
**Sixth:** M1 Garand, an early 20th-century semi-automatic rifle and the first to be adopted as standard military issue.
**Seventh:** AK-47, a mid 20th-century gas-operated, magazine-fed automatic rifle.
**Eighth:** FAMAS, a late 20th-century selective fire, bullpup assault rifle.

# Field Guns

M777 Ultralight Howitzers

Dhanush 155 mm

Courtesy: Google images

# Automation

- Increased labour productivity
- Reduced labour cost
- Improved product quality (Less human intervention)
- Reduced manufacturing lead time

# Classification

- Fixed automation ( Eg: Water wheel, Gravity machine)
- Programmable automation (One set of program for the whole operation, Combination of hardware and software)
- Flexible automation (Programmed for various operations, Computer integrated manufacturing Eg: Automobile assembly line)

Courtesy: Google images

# Automation vs. robots

- Automation –Machinery designed to carry out a specific task
  - Bottling machine
  - Dishwasher
  - Paint sprayer

- Robots – machinery designed

  to carry out a variety of tasks
  - Pick and place arms
  - Mobile robots
  - Computer Numerical Control machines


Courtesy: Google images

# Automation in cars

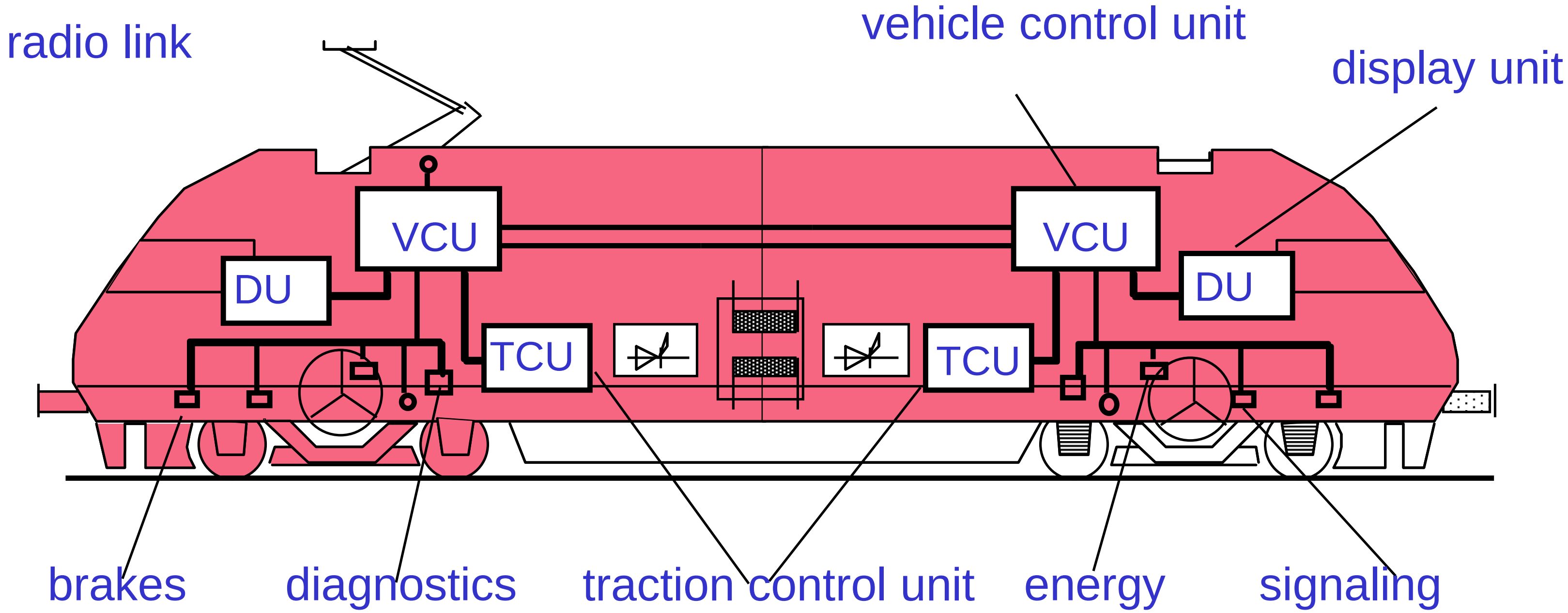
Embedded systems
Micro controllers

Traditional: appliances control (windows, seats, radio,..)
Motor control (exhaust regulations)
Critical new applications: ABS (anti-skid) and EPS (stability),
Brake-by-wire, steer-by-wire (“X-by-wire”) increased safety ?
LIDARS for distance measurement and braking

Courtesy: Google images

# Automation in rail vehicles

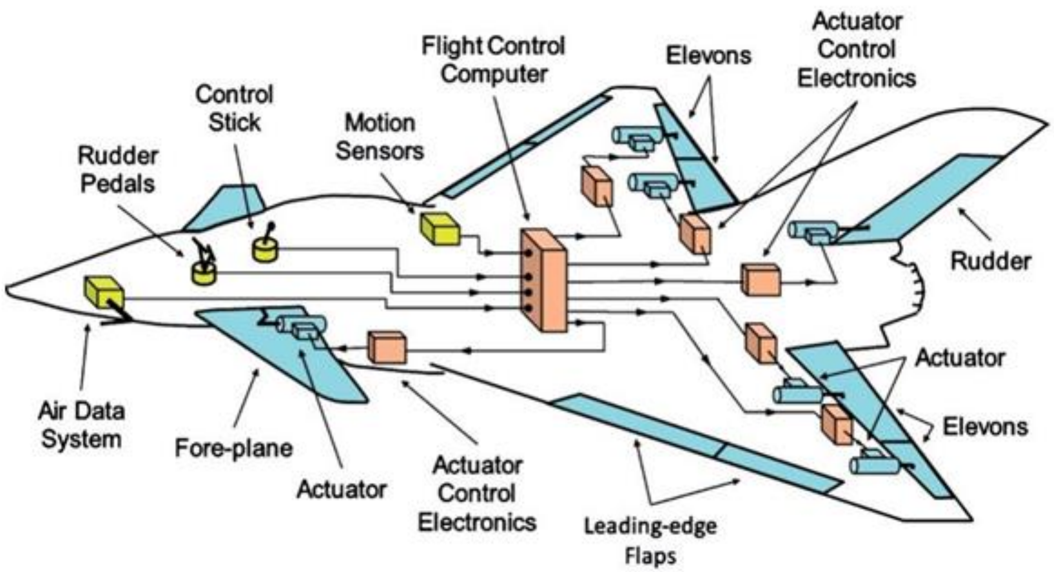
There are more than 20 interconnected computers on a locomotive




Benefits: reduce operation costs, faster diagnostics, better energy management, automatic train control.

Courtesy: Google images

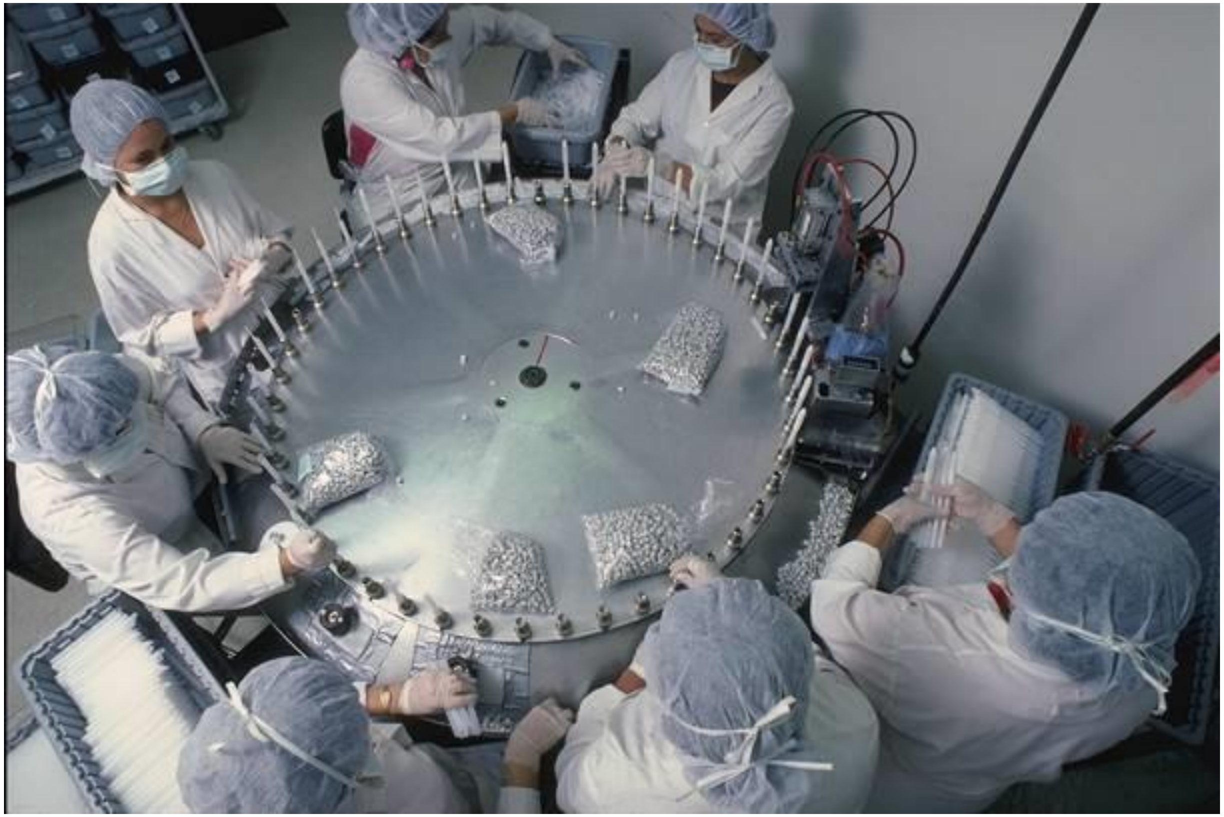
# Automation in airplanes




“Avionics”:
flight control (safe flight envelope, autopilot, “engineer”)
flight management
flight recording (black boxes, turbine supervision)
diagnostics
“fly-by-wire”
high reliability

Courtesy: Google images

# Automation in pharmaceutical Industry



Typical of batch processes.

Inventory
Recipe management
Packaging
Sampling
Tracking & tracing
Comply with government rules:

Courtesy: Google images

# Substations

protection (Lines, transformers, generators) very high speed response
control (remote or local) to guarantee power flow, safe operation (interlocking)
measurement (local and remote), electricity bill, power flow in grid
Smart grids

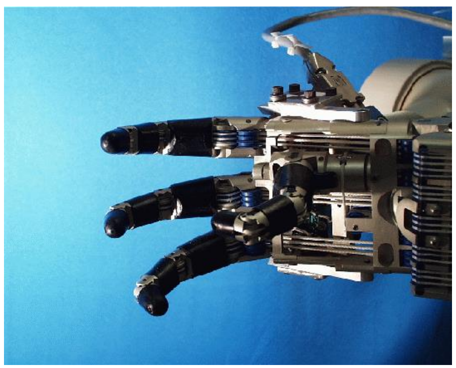
Courtesy: Google images

# Robots

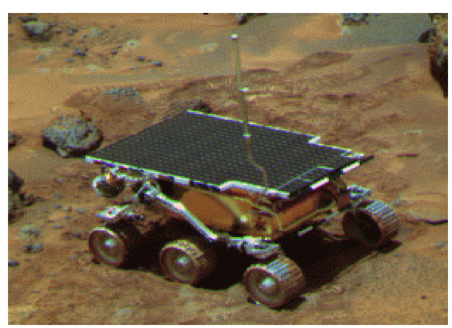
## "Robot" coined by Karel Capek in a 1921 science-fiction Czech play

Def: "A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks." (Robot Institute of America)

### Robot Manipulators




### Mobile Robots



Courtesy: Google images

## Walking robots

## Humanoid robots

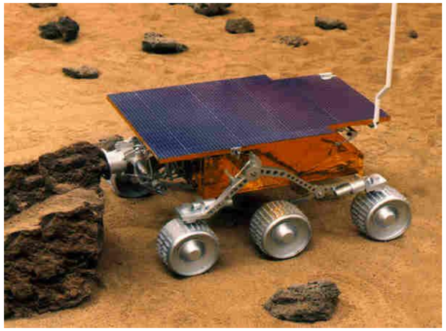
Artificial intelligence

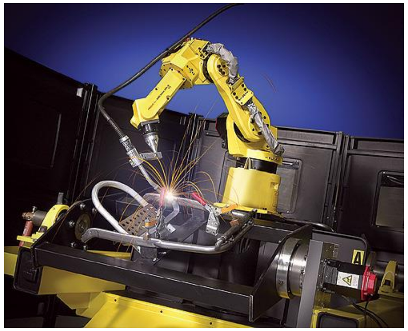
Courtesy: Google images

# Ideal tasks of robots

Tasks which are:

- Dangerous
  - Space exploration
  - chemical spill cleanup
  - disarming bombs
  - disaster cleanup
- Boring and/or repetitive
  - Welding car frames
  - part pick and place
  - manufacturing parts.
- High precision or high speed
  - Electronics testing
  - Surgery
  - precision machining
  - Rescue programs





Courtesy: Google images

# Control

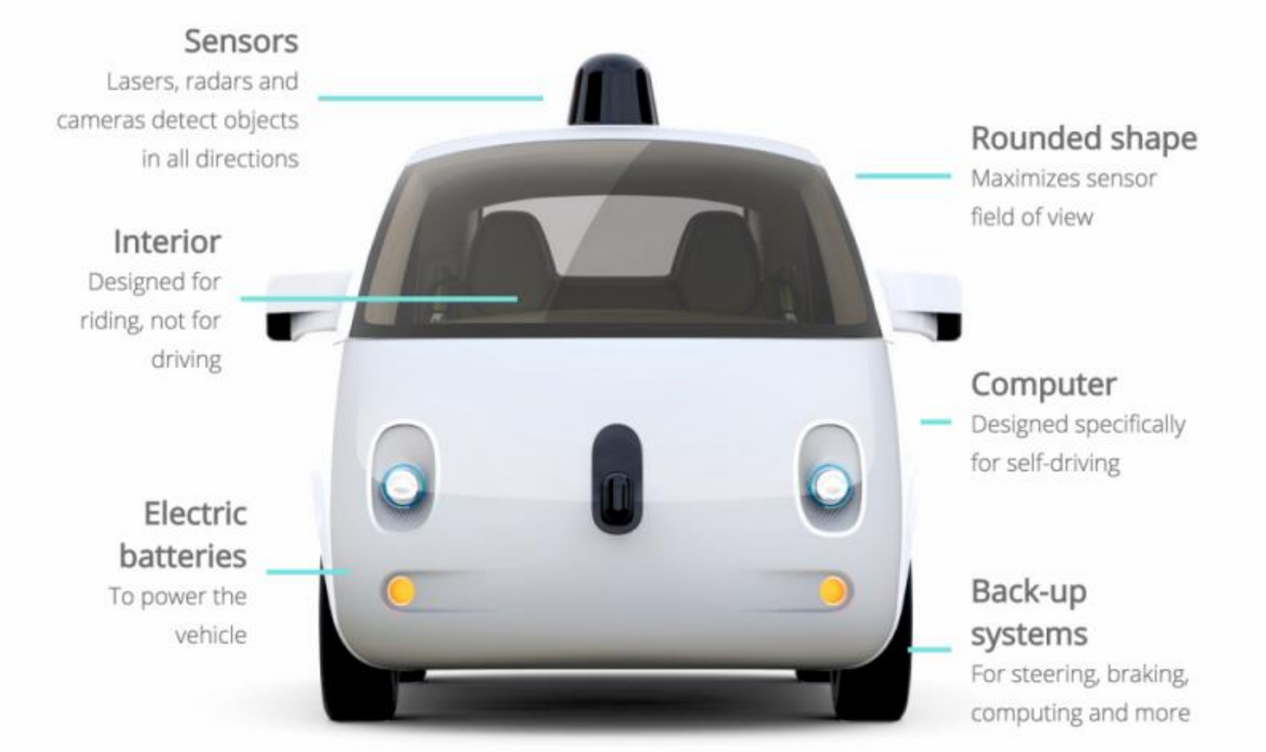
- Open loop, i.e., no feedback, deterministic
- Closed loop, i.e., feedback, maybe a sense of touch and/or vision

## Feedback control

- Rotation encoders
- Cameras
- Pressure sensors
- Temperature sensors
- Limit switches
- Optical sensors
- Sonar

Courtesy: Google images

# Driverless-car



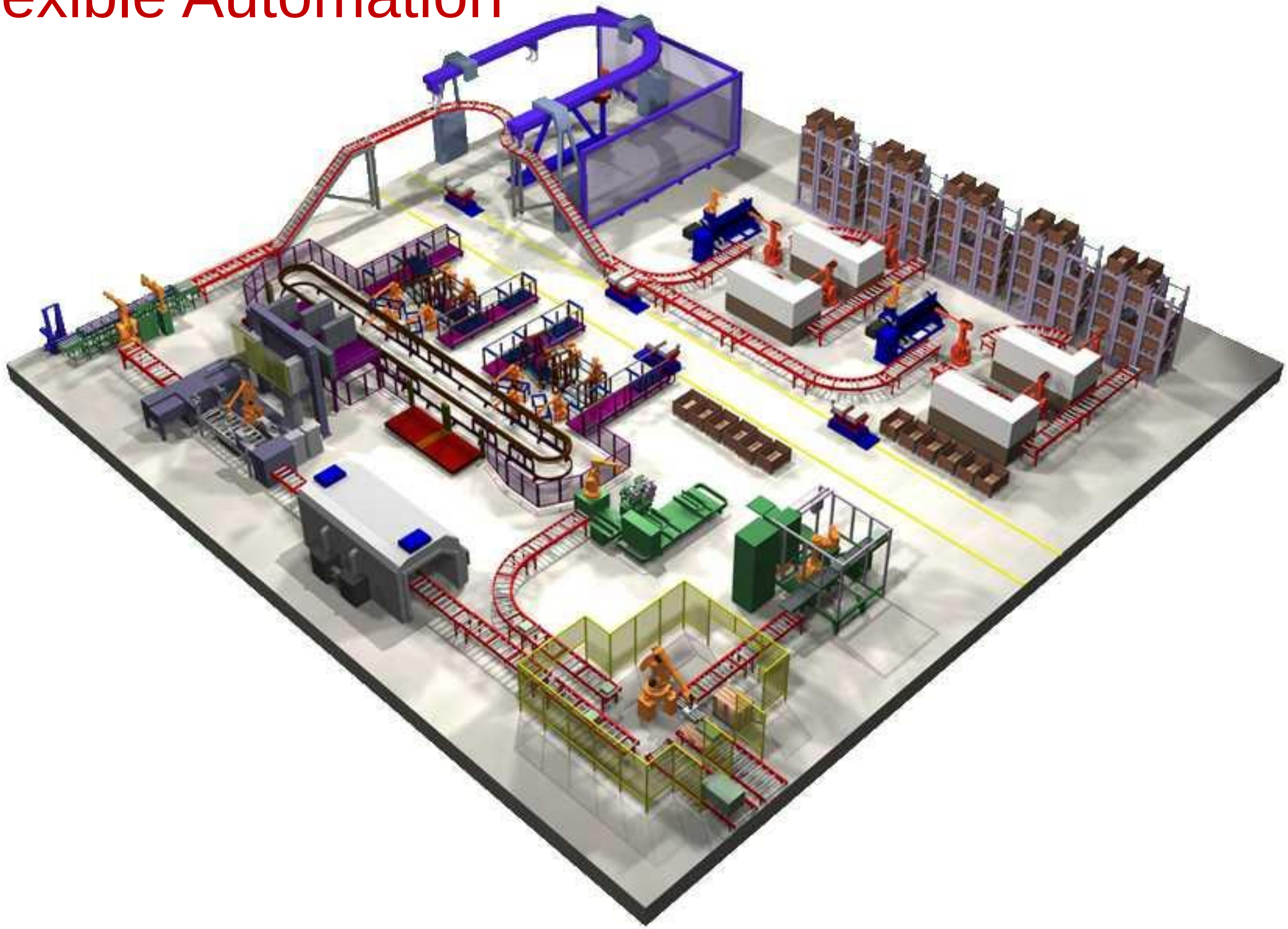


Courtesy: Google images

# Automated assembly lines

Courtesy: Google images

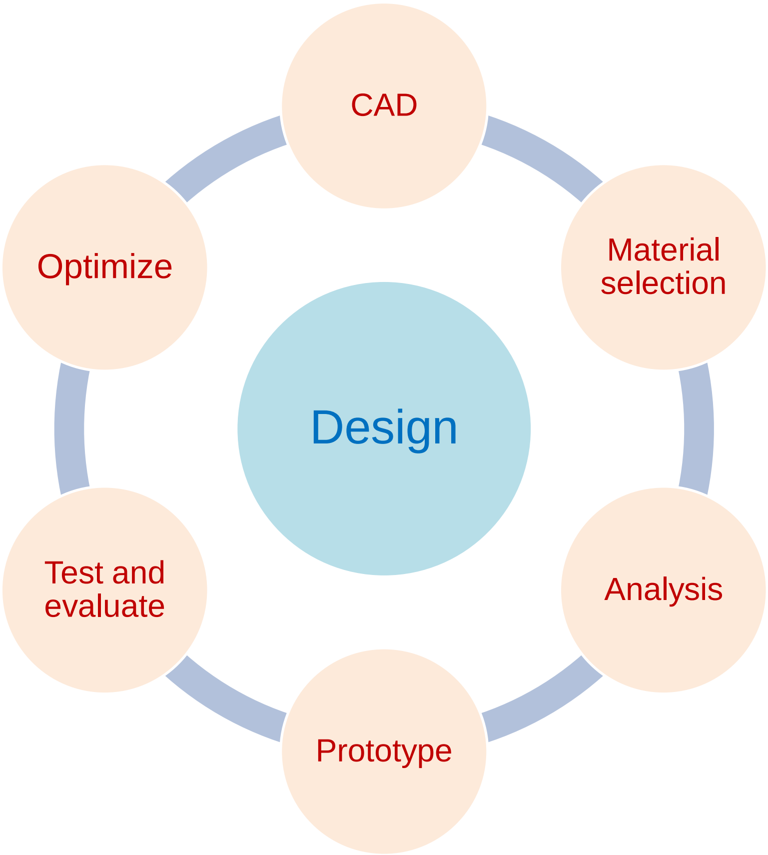
# Flexible Automation

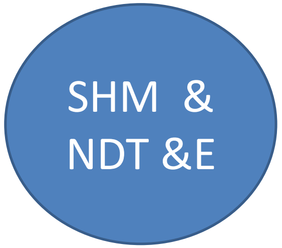


numerous conveyors, robots, CNC machines, paint shops, logistics.
Download from production management,  connection to administration

Courtesy: Google images

# Engineering design



Thank you