5.3 Propulsion System:

As we have discussed earlier, the past few years have seen a resurgence of interest in LTA (Lighter-Than-Air) vehicles being developed around the world use advanced technologies and novel configurations and features for their outstanding performance. Stratospheric airships as a high altitude long-endurance platform are being globally perceived as the most viable solution with acceptable service reliability and the total cost for applications such as Communications, Earth observation, Meteorology, Astronomy, and Military applications such as Reconnaissance, coastal observations and Missile launch and detection. These airships are operated in a quasi-stationary position at an altitude of typically between 17 and 22 km in Stratosphere, and are thus referred to as stratospheric airships.

Apart from its structure, aerodynamics etc. one of the most critical systems is Propulsion system for station-keeping as well as for the payload and applications which is provided from lightweight solar cells in the form of large flexible sheets during the day and additional energy is stored in regenerative fuel cells, which provides all the power requirements at night; coupling of vectorable propellers for cruise/lift augmentation; bow and stern thrusters for low speed maneuverability.

5.3.1 Basic principle:

The basic principle for generating thrust is the usage of a propeller due to the low speeds to be achieved. There are different possibilities to generate the required torque. The standard and known solution is based on combustion engines and does not need further explanation. Electric powered airships are slightly different. Due to the fact of not burning fuel, the weight of the airship remains constant during operation, which allows to fly always closer to EQ and therefore more efficient. Due to the low energy density of batteries etc. an optimized energy management is required. The reduction of drag in order to reduce power demand is of major importance. Batteries can be supported by solar cells attached on top of the envelope, taking advantage from the large surface of the hull [68].

A much further developed concept is using regenerative fuel cells in combination with solar cells to allow indefinite endurance. Airships have the advantage that the storage of the reactants is much simpler because enough volume for unpressurized storage is available. Ideally the solar generator is based on thin-film solar cells as these are better able to follow the shape of the
envelope. Crystal solar cells as have been used for Lotte and Speedy are flexible enough as well, but attaching them to the envelope is difficult [68].

Compared to fixed wing aircraft, Airships are much less sensitive to payload weight and high altitudes. Propulsion systems would need to deliver far less power and produce less waste heat, but, because of the low speeds, the cooling that is needed is rather more difficult to obtain. However, Takeoff and Landing is a much larger issue in the design, and the large vehicles will be subject to restrictions in high winds.

5.3.2 Historic overview of propulsion system:

Historically Goodyear Aerospace Corp., that undertook actual development work under a contract from the U.S. Air Force for project called as High Platform, employed a natural shape balloon carrying a power pack driving a large helicopter-type rotor for propulsion. Other examples:

- **StratSat airship system**: The airship is propelled and steered by means of a 'Contra-Rotating Coned Rotor' mounted on a tail cone at the rear of the envelope, as part of the compound propulsion system. Other examples are:
  - **HALE-D**: Driven by two electric propulsion motors, the HALE-D is powered by thin-film solar cells and rechargeable lithium ion polymer batteries.
  - The stratospheric airship programs in Japan have reported the use of solar RFC energy storage system and electric propulsion

The most aggressive design was the 1982 Lockheed HI-SPOT (High Altitude Surveillance Platform for Over-the-Horizon Targeting). The airship was with an envelope volume of 142,000 m³, 154 m length and 42.2 m diameter with a gross weight of 11,750 kg. It was a true airship with ballonets for buoyancy control and a four-layer laminate skin. The body was a low-drag laminar shape and active boundary-layer control was used to produce an extremely low drag coefficient. HI-SPOT was powered by four new-generations liquid-cooled, turbo-charged, liquid hydrogen fuel IC engines. The propeller was to be 26 m in diameter, operating at 100 rpm with a projected efficiency of 90% at 20 km. The vehicle had a maximum speed of 40 m/s. HI-SPOT would be capable of a 6000 - nm transit, a payload of 250 kg, 4 kW of payload power, and could maintain station for 30-155 days at any latitude. The design was aggressive and represented an optimum use of early 1980s technology. Figure 5.11 is an illustration of the HI-SPOT airship.
HI-SPOT evolved from an earlier solar regenerative propulsion design. The weight of the fuel cells and solar array became very large in the high-speed cases where high power was required. The heavy solar propulsion system was used at a few percent of its capacity throughout most of the flight where winds were typically less than 10 m/s. It was concluded that consumable fuel was far more efficient when a wide range of speeds are needed. This result can be generalized and it is unlikely that solar powered airships will be practical for high-speed flight. Only in cases where operations can be limited to average or a moderate condition is a solar-electric airship viable.

HALEs are equipped with an engine for mobility and stable positioning against stratospheric winds. The altitude of 20km is high enough to give local or regional coverage of about 100km in diameter and also offers the advantage of minimum wind speeds. Solar cells covering the upper, sun-oriented parts of the airship skin gather energy at daytime to power a high-efficiency electric engine, which drives a large propeller and feed energy into a storage and conversion system, from which it is drawn for night time propulsion and operation of the vehicle.

![Fig 5.11: Schematic drawing of the Lockheed HI-SPOT airship](image)

Stratospheric airships can be designed to reach and operate at the desired altitude, and can be brought down to earth, refurbished and re-deployed. Once the platform is positioned, it can immediately be brought into service without the need to deploy a global infrastructure or constellation of platforms to operate. Propulsion system comprises of the main electric motors with propellers mounted at the bow and stern of the airship. These propellers provide longitudinal thrust (to counter the prevailing
stratospheric winds). There is provision of small thrusters for producing lateral forces for low speed maneuvers. The idea behind this combination of motors and propellers is to enable the airship to hold station within, say, a 1 km X 1 km X 1 km cube.

Onboard energy source is required to power the propulsive electric motors, mission payload and airship systems. Literature suggests the solar electric propulsion system to be most suitable for long endurance station keeping application. The solar array provides the sole source of renewable energy for the airship. In most cases, the solar array is placed over the upper quarter of the hull, extending over approximately three-quarters of the length. The array can be realigned to the daily sun location/angle by the roll/rotation of the whole airship. Additional energy collected by the solar array is stored in storage system for use during night times.
Except the propulsion system, the payload module homes all of the primary systems. These systems are closely packed within a highly insulated module ensuring efficient heat and energy management.

5.3.3 Design Calculation Methodology (by Prof. Pant, IIT Bombay):

The design methodology suggested by Prof Pant is divided in two parts; the first deals with the shape and material for the envelope, and the second with the propulsion system. These are cross-linked to get the proportionate variation with respect the drag; since drag is a function of envelope shape and size.

The propulsion system power consumption is assumed constant over the whole day. The available solar energy is directly fed into the engine to minimize transformation losses. The difference between maximum generator output and engine input is defining the maximum power that the storage system must be able to cope with. For long discharging times, the characteristics of regenerative fuel cell system are better than that of batteries.