Temasek Defence Systems Institute

SUSTAINABLE AVIATION

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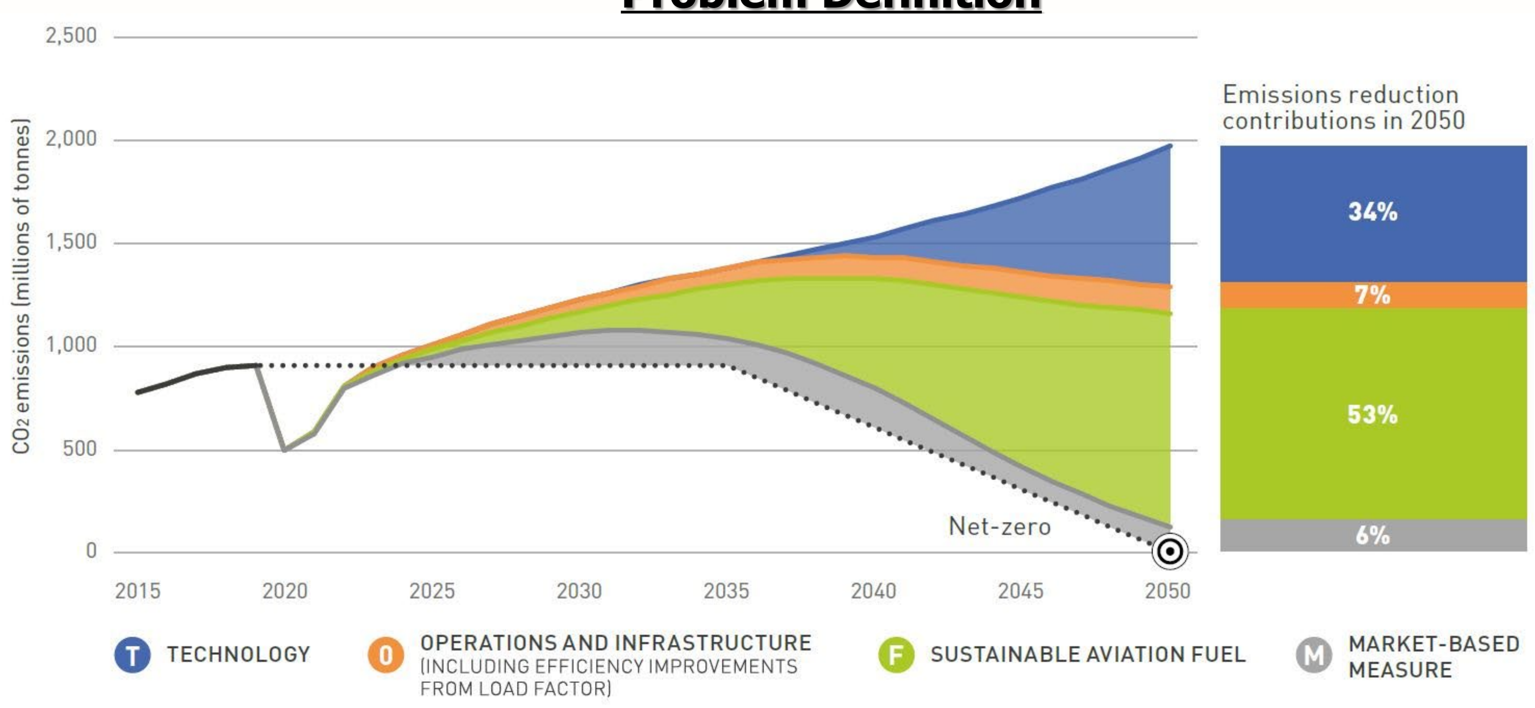
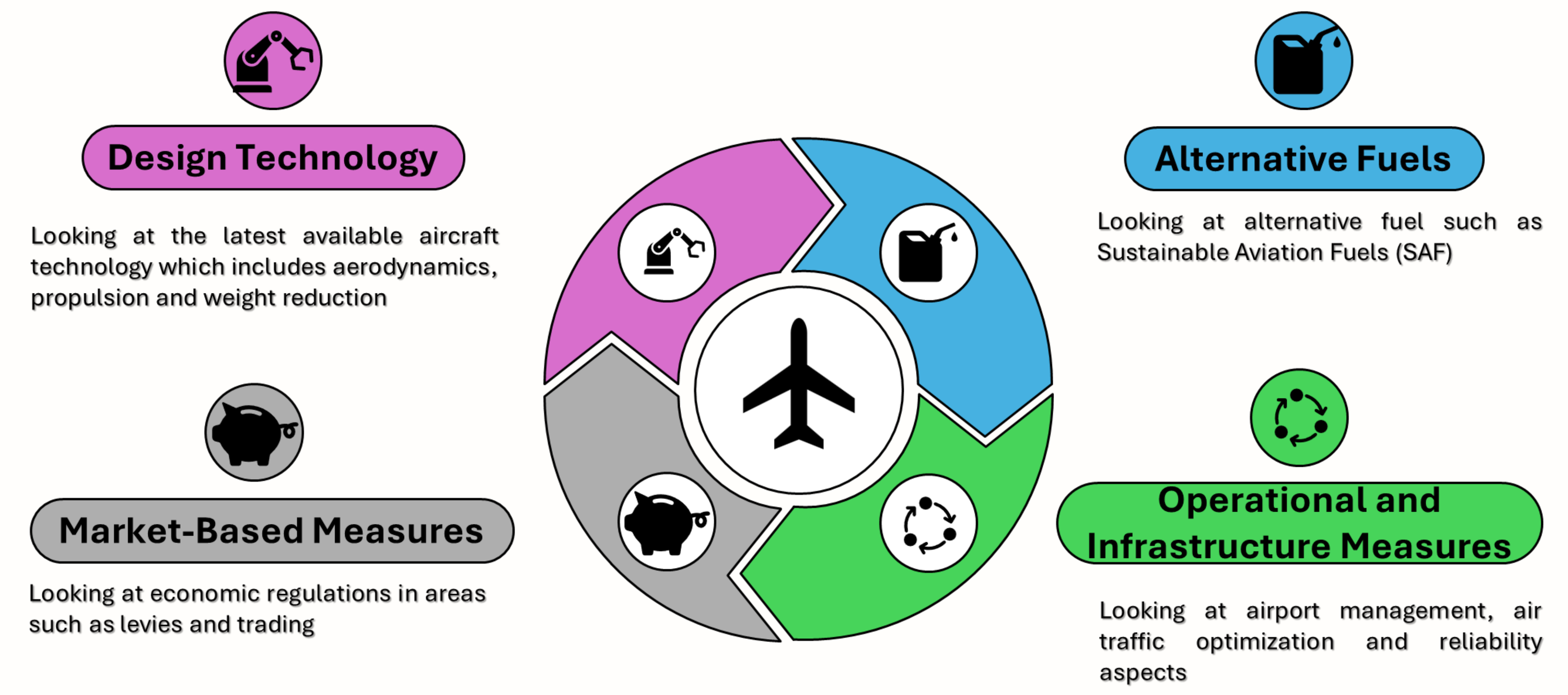
Problem Definition



The central traffic growth projection used shows that, by 2050, over 10 billion passengers will fly each year a distance of 22 trillion revenue passenger kilometres. Without any intervention (keeping the current fleet and current level of operational efficiency), this activity would generate close to 2,000 megatonnes of CO2 and require over 620 Mt of fuel.

Four-Pillar Approach



Sustainable aviation can only be achieved through an integrated approach combining the 'Four Pillars', where each pillar contributes in its own unique way in achieving a carbon-neutral growth while managing their interdependencies and inherent complexities.

Lifecycle Emission Analysis (LCA)

Summary	Lifecycle Emission Value, LEF (in g CO2e/MJ)
Conventional Aviation Jet Fuel	88.9
SAF (Used Cooking Oil)	16.7
SAF (Tallow)	25.4

- The GHG reduction benefits of SAFs compared to fossil-derived jet fuels are due to the CO2 uptake of biomass feedstocks, where CO2 from fuel combustion is offset by carbon uptake during photosynthesis, resulting in net-zero fuel combustion CO2 emissions.
- Even though the lifecycle emission values for SAF is much lower than conventional aviation jet fuel, a lifecycle cost analysis will be performed between conventional aviation jet fuel and SAF to assess if SAF is economically viable to be produced.

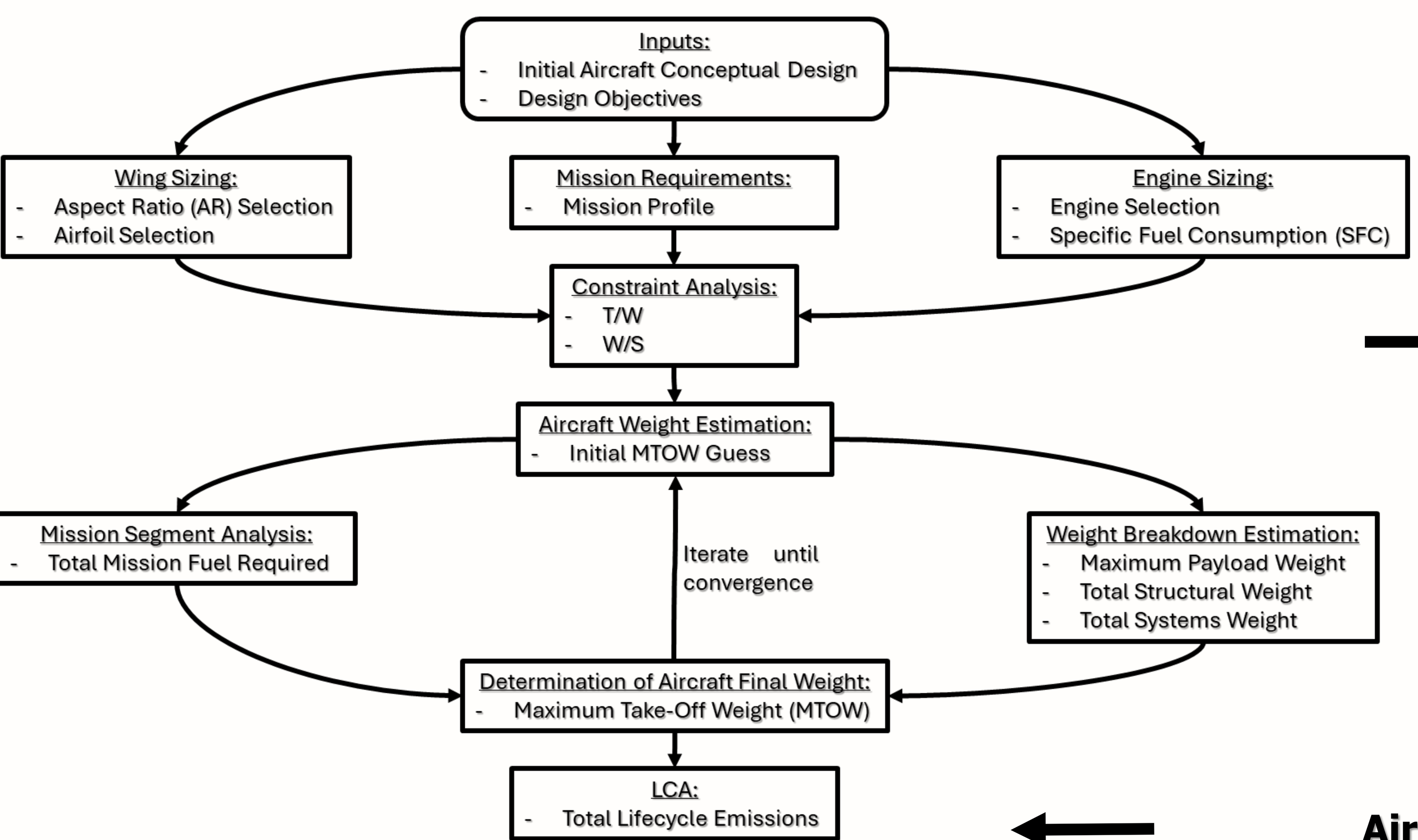
Lifecycle Cost (LCC) Analysis

Summary	Lifecycle Cost per Barrel (in USD$)
Conventional Aviation Jet Fuel	503.10
SAF (Used Cooking Oil)	1507.14

- This lifecycle cost analysis indicates that SAF is approximately 3 times more expensive than conventional aviation jet fuel which is in agreement with current literature that indicates that SAF is typically between 3-5 times more expensive than conventional aviation jet fuel
- This is mainly due to the low production volume of SAF, which means that it is difficult to achieve low economies of scale from its production and the lack of a widespread infrastructure dedicated to the production, storage, and distribution of SAF contributes to its higher costs. In addition, this infrastructure deficit hampers the ability of SAF to compete on a level playing field with traditional jet fuel, given the latter's established and efficient supply chain.

In summary, The LCA and LCC analyses indicate that SAFs can lead to significant reductions in lifecycle emissions as compared to conventional aviation jet fuel, though economic feasibility remains a key barrier to large-scale implementation.

Aircraft Conceptual Design & Sizing



Aircraft Configuration Design Strategy

Following a study that was performed looking at the different aircraft configurations of the future, that the strut-braced wing (SBW) aircraft demonstrates the greatest potential as a future generation passenger jet.

Design Objectives (Top-Level Requirements

Strut-Braced Wing (SBW) Aircraft

Passengers	200
Range	4000 nm
Maximum Cruise Altitude	FL430
Maximum Cruise Speed	Mach 0.8
Maximum Approach Speed	70 m/s
Take-Off Distance	2500 m
Landing Distance	1800 m

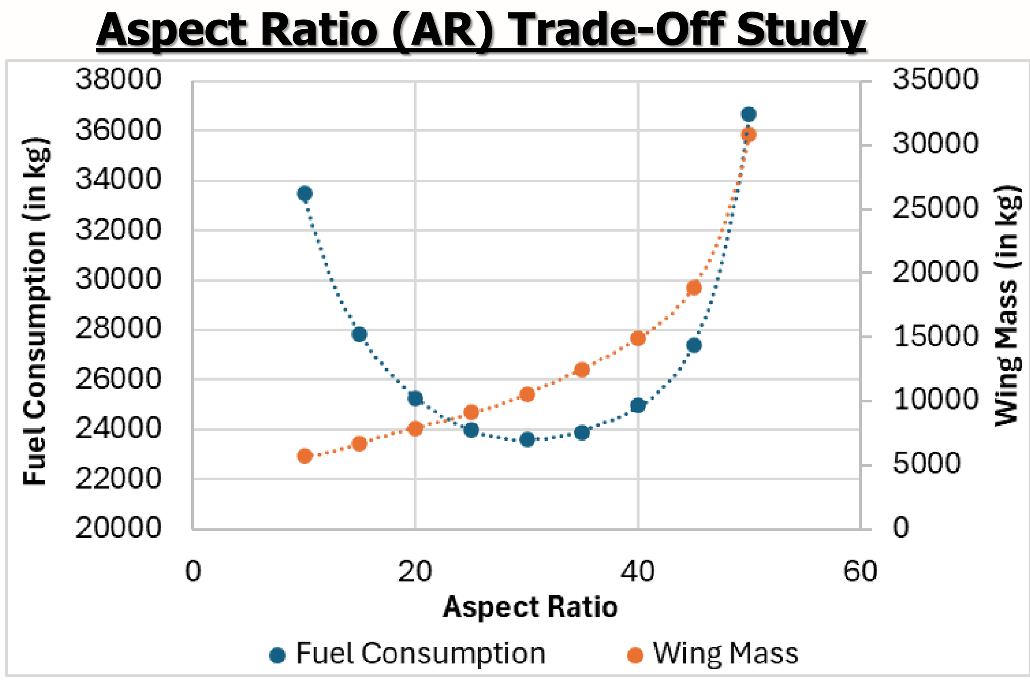
Aircraft Weight Estimation

Component	Mass (in kg)
Fuselage	5996.70
Wing & Wing Struts	8220.17
Tail Unit	1965.51
Undercarriage	3467.41
Powerplant	5312.47
Total Structural Mass	**24652.26**
Fuel System (Including Fuel Tank & Residual Fuel)	1012.79
Flying Control System	1022.28
Hydraulics and Pneumatics System	966.63
Electrical System (Including APU)	2229.10
Environmental Control System	1285.62
Miscellaneous Equipment	2090.92
Furnishings	9270.00
Total Systems Mass	**17877.34**
Total Fuel Mass	**27852.05**
Total Payload Mass	**20955.95**
Maximum Take-Off Weight	**91247.60**

Aircraft Lifecycle Emissions

Description	Symbol	Value	Units	Remarks
Airbus A321 NEO				
Maximum Fuel Capacity	L_F	32940	(in litres)	For an Airbus A321 NEO
Maximum Fuel Required	W_F	26615.52	(in kg)	Computed value for kerosene using Table 1
Total Energy Consumption	E	1149790.46	(in MJ)	Computed value for kerosene using Table 1
Lifecycle Emissions	L_E	1.02E+08	(in gCO_2)	Computed value for kerosene using Table 2
Maximum Fuel Required	W_F	28657.80	(in kg)	Computed value for SAF using Table 1
Total Energy Consumption	E	1114788.42	(in MJ)	Computed value for SAF using Table 1
Lifecycle Emissions	L_E	1.86E+07	(in gCO_2)	Computed value for SAF (used cooking oil) using Table 2
Total Lifecycle Emissions	L_E	6.04E+07	(in gCO_2)	Using an equal blend of kerosene and SAF (used cooking oil)
SBW Aircraft Design				
Maximum Fuel Required	W_F	27852.05	(in kg)	Computed value for SAF using Table 1
Total Energy Consumption	E	1083444.80	(in MJ)	Computed value for SAF using Table 1
Total Lifecycle Emissions	L_E	1.81E+07	(in gCO_2)	Computed value for SAF (used cooking oil) using Table 2
Percentage Reduction in Total Lifecycle Emissions = 70%				

Aspect Ratio (AR) Trade-Off Study



Using this optimized AR value, if biofuel (used cooking oil) was used, the SBW aircraft design showed an 75% reduction in overall aircraft emissions while if biofuel (tallow) was used, the SBW aircraft design showed an 64% reduction in overall aircraft emissions as compared to the A321 NEO.

The conceptual SBW aircraft design further illustrates the potential of novel configurations to improve aerodynamic efficiency and reduce fuel consumption, especially when coupled with SAF usage.

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