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A METHODOLOGY FOR DETERMINATION OF BASELINE SPECIFICATIONS OF A NON-RIGID AIRSHIP

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ABSTRACT

This paper presents a methodology for arriving at the baseline specifications of a non-rigid airship of conventional configuration, given the performance and operational requirements. Specifically, the methodology calculates the envelope volume required to carry a user-specified payload, and also arrives at the mass breakdown, and performance estimates. Alternatively, the payload that can be carried by an airship of specified envelope volume can also be estimated. Sensitivity of parameters such as pressure altitude, ambient temperature, cruising speed, Helium purity level, engine power, envelope length to diameter ratio etc. on the payload available or envelope volume required can also be determined. The baseline specifications of two airships for transportation of goods and passengers under hot and high conditions obtained using this methodology are presented. Results of sensitivity analysis for one airship are also discussed.

NOMENCLATURE

Symbol	Description
AR	Aspect ratio
C	Chord (m)
C_{DV}	Coefficient of volumetric drag
D	Drag (N)
H	Altitude (m)
k_{alt}	Engine power lapse factor
k_{Drag}	Drag factor
$k_{s\ e}$	Envelope surface area factor
$k_{v\ e}$	Envelope volume factor
L	Lift (kg)
l	Length (m)
l/d	Length to diameter ratio
N	Number
P	Power (HP), or Total Pressure (N/m^2)
$p_{offtake}$	Ratio of power off-take for accessories
R	Range (km)
r	Radius (m)
R_e	Reynolds number
S	Surface area (m^2)
$\hat{S}$	Area ratio
sfc	Specific fuel consumption (lb/HP-hr)
T	Temperature
t/c	Tip to chord ratio
V	Volume (m^3)
V	Velocity (kmph)
v	Volume ratio
W	Weight (kg)
$\hat{w}$	Specific weight per unit area (kg/m^2)
Δ_{ISA}	Temperature variation from ISA
Δ_p	Internal Overpressure (N/m^2)
η	Efficiency
ρ	Density (kg/m^3)
σ	Density ratio
τ	Taper ratio

Sub-scripts	Description
0	Standard conditions
a	Air
air	Airlines (inside envelope)
b	Ballonet
bpc	Ballonet pressure control
btr	Ballonet trimming
cat	Catenaries
con	Control system
cr	Cruise
crew	Crew
ctr	Control
duct	Propulsive duct
e, env	Envelope
e&i	Electrics & Instruments
empty	Empty
eng	Engine
f, fin	Fin
fuel	**Fuel**
fte	**Fin trailing edge**
gon	**Gondola**
h	**Helium**
inst	**Installed**
lg	**Landing gear**
max	**Maximum**
min	**Minimum**
misc	**Miscellaneous items**
n	**Nose**
pat	**Patches**
pay	**Payload**
prop	**Propeller**
R	**Root**
rig	**Rigging**
sus	**Suspension**
T	**Tip**
tr	**Transmission system**
vec	**Thrust vectoring system**

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INTRODUCTION

The three phases of engineering design are conceptual, preliminary and detailed design. Of these, the conceptual design phase is the least in terms of total duration and investment; which is approx. 5% of the total. However, its importance and significance can be judged from the fact that decisions taken during this phase have a direct bearing and influence on the effort and investment in the phases that follow. One of the most important activities in the conceptual design phase are design studies that lead to the identification of the baseline requirements of the final product. Sensitivity analyses which identify the leverage of various design variables on the performance and operational parameters are an essential part of these studies.

Several methodologies and procedures for obtaining baseline specifications of fixed wing aircraft are available, such as Loftin[1] for transport aircraft. However, no such methodology is available, at least in open literature, for conceptual design studies of airships. Further, there seems to be no standard procedure to identify the capabilities and limitations of an existing airship. For instance, to determine the payload capacity of an airship at a particular altitude, one has to either refer to the airship's performance manual or apply some simplistic thumb-rules.

This work was driven by a need to fulfill this gap in literature, i.e., to develop a methodology for arriving at the baseline specifications of an airship that meets certain operational and performance requirements specified by the user. This methodology also enables the designer to carry out sensitivity studies related to the design parameters, as well as investigating the effect of incorporating certain design features, or choosing from among some possible design options.

DESCRIPTION OF THE INPUT PARAMETERS

The issues related to operation and design synthesis of airships are succinctly explained by various contributors in Khoury & Gillett[2]. Through a study of this literature, the key parameters that affect the operation and configuration of airships and performance requirements that strongly affect their design were identified. Such parameters, which constitute the list of inputs to the methodology, can broadly be classified under three categories, as listed in Table 1.

The pressure altitude and atmospheric properties have a direct bearing on the volume of the airship envelope and the payload capacity. The difference between the pressure altitude and the minimum operating altitude determines the volume of the ballonets. The performance requirements listed in Table 1 directly influence the power-plant sizing and fuel requirements.

Operation related parameters	**Performance Requirements**	**Configuration related parameters**
Pressure altitude	Range	Fin layout
Atmospheric properties	Cruising altitude	No. of engines
Minimum operating altitude	Cruising speed	Envelope length to diameter ratio
Helium purity level	Pressure altitude	Ballonet volume for trim
Power off-take for engine driven accessories	Pressure altitude	Internal overpressure

Table 1: List of input parameters

Apart from studying the effect of the input parameters, the designer would also like to investigate the effect of incorporating certain design features, and choosing among various configuration related options. The list of design features and options that can be studied in this methodology are listed in Table 2.

Design Feature	**Option 1**	**Option 2**
Engine Type	Diesel	Petrol
Engine Charging	Normally aspirated	Supercharged
Propeller Type	Ducted	Un-ducted
Ballonet Type	Separate	Integral
Thrust Vectoring	Present	Absent
Fin Layout	Cross	Plus
Transmission system	Simple	Complex

Table 2: List of design features and options

The methodology can be applied in either of the two modes; the *design* mode or the *evaluation* mode. In the *design* mode, which is relevant when a new airship is being designed, the envelope volume required to carry a user-specified payload is estimated. In the *evaluation* mode, which is relevant when the capability of an existing airship is being evaluated, the payload that the airship can carry for a specified envelope volume is estimated. Apart from this, the methodology also calculates the geometrical parameters of the envelope and the ballonets, and determines parameters such as max. speed at cruising altitude, total installed power at sea-level static conditions, fuel weight, the weight breakdown of major assemblies and empty weight.

OUTLINE OF THE METHODOLOGY

In the *design* mode, the calculations are initiated with an assumed value of envelope volume. The net lift available at the operating altitude is calculated. The next step is the estimation of geometric parameters of the airship, which include the dimensions of the envelope, ballonets and the fins. This is followed by the estimation of drag coefficient, and hence the installed power required and fuel weight. The last step is the estimation of weight breakdown of various components and hence the empty weight, through which the payload capacity is estimated. If this payload does not match the desired value, then envelope volume is adjusted and the calculation are repeated till convergence.

The flow chart of the methodology in the *design* mode is shown in Figure 1.

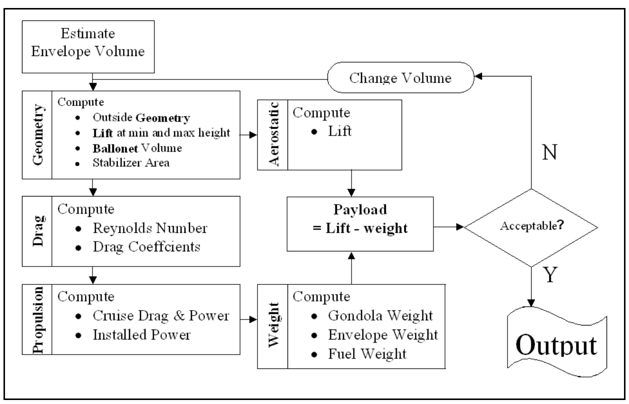

Figure 1. Flow chart of the methodology

In *analysis* mode, only the inner loop is executed, since it directly estimates the payload available for a specified envelope volume.

DETAILS OF THE METHODOLOGY

A description of the various sub-modules of the methodology is given below.

Aerostatics Sub-module

The net lift of an airship is directly affected by the variation in the air pressure and temperature in the atmosphere and inside its envelope. The net lift reduces with increase in altitude, and is the minimum at pressure altitude. Using the methodology outlined by Craig in Khoury & Gillett[2], the net lift available at pressure altitude H_{max} can be calculated as

$$L = V_e(1 - V_{btr}) \cdot \sigma_{aHmax}\left(\rho_{a0} - \rho_{h0}\left(1 + \left(\Delta_p / P_{Hmax}\right)\right)\right) \quad (1)$$

Geometry sub-module

In this sub-module, the length, maximum diameter, and surface area of the envelope and ballonets are estimated.

Envelope geometry For airship envelopes of conventional shapes, it can be shown that the envelope volume and surface area satisfy the relations

$$\frac{V_e}{l_e^3} = \frac{k_{ve}}{(l/d)_e^2} \text{ and } \frac{S_e}{l_e^2} = \frac{k_{se}}{(l/d)_e} \quad (2)$$

Young[3] has shown that for envelopes based on the R-101 airship shape, the factors k_{se} and k_{ve} are 2.33 and 0.465, respectively. A study of existing airships with envelopes of double ellipsoid or similar shape was carried out, based on which these factors were estimated to be 2.547 and 0.5212, respectively.

Eq. 2 can be recast to determine envelope length and surface area for known volume and $(l/d)_e$ ratio as

$$l_e = \sqrt[3]{(V_e \cdot (l/d)_e^2 / k_{ve})} \text{ and } S_e = k_{se} l_e^2 / (l/d)_e \quad (3)$$

Ballonet geometry The total ballonet volume is

$$V_b = (v_{bpc} + v_{btr}) \cdot V_e \quad (4)$$

The volume of ballonet required for control purposes can be calculated using

$$v_{bpc} = 1.0 - (L_{Hmax} / [\sigma_{Hmin}\left(\rho_{a0} - \rho_{h0}\left(1 + \left(\Delta_p / P_{Hmin}\right)\right)\right) V_e)] \quad (5)$$

To fix the appropriate value of v_{btr}, the ratio of total ballonet volume to envelope volume was found for 12 airships, and then compared with the ratio necessary for pressure control for operation under ISA and Δ_{ISA}=15, as shown in Fig. 2. It was assuming that the excess ballonet capacity has been provided for trimming purposes, or to cater to more severe operational requirements. The effect of increase in v_{btr} on the lift and payload is plotted in Fig. 3, which indicates that this ratio should be kept as small as practically possible.

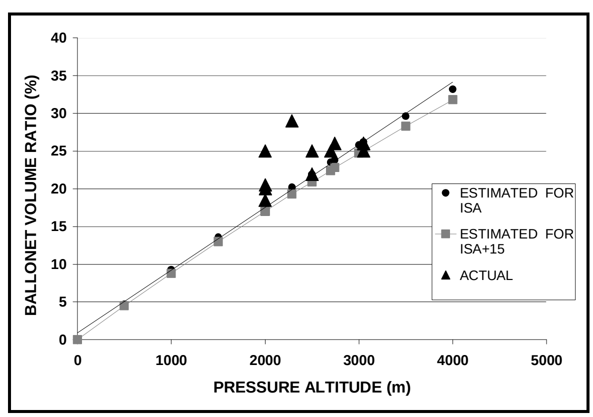

Fig 2. V_{bpr} v/s H_{max} for 21 airships

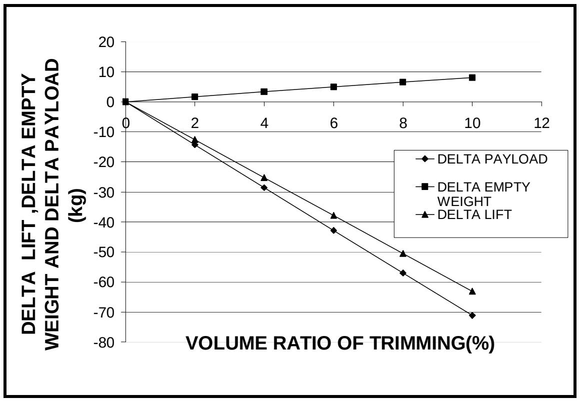

Fig. 3 Effect of V_{btr} on W_{Pay}, W_{empty} and Lift

Assuming a twin spherical ballonet layout, radius and surface area of each ballonet can be estimated as

$$r_b = \sqrt[3]{3V_b/8\pi} \text{ and } S_b = 2\pi \cdot (r_b)^2 \quad (6)$$

Fin geometry The size and location of fins are a function of the desired control characteristics of the airship. Geometrical data related to fins of 15 airships was collected, analyzed and tabulated to standardize the fin geometry, as shown in Fig. 4

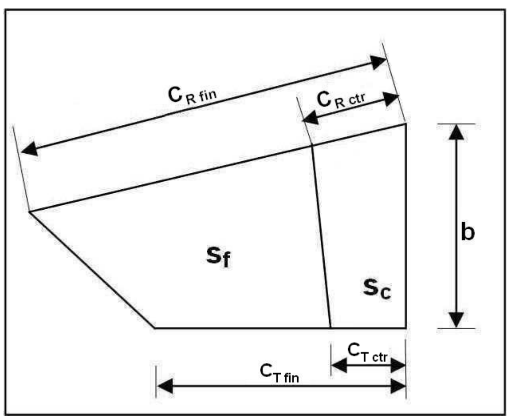

Fig. 4 Schematic view of a fin

Several non-dimensional ratios were calculated, and the averages of these ratios were used in the methodology, as listed in Table 3. The fin dimensions and their relative location on the envelope were decided using these ratios.

Parameter	Formula	Value
Tail area ratio	$N_f .(S_f + S_{ctr})/ S_e$	0.061
Fin location ratio	l_{fte}/l_e	0.907
Fin taper ratio	$C_{T f}/C_{R f}$	0.596
Fin aspect ratio	$b^2/(S_f + S_{ctr})$	0.602
Control area ratio	$S_{ctr} /(S_f + S_{ctr})$	0.258
Control taper ratio	$C_{T ctr}/C_{R ctr}$	0.868

Table 3. Parameters derived from statistical data

Drag sub-module
For most airships the flow over the hull is turbulent and the volumetric drag coefficient C_{DVe} for these conditions is calculated using the following formula due to Hoerner[4], reported by Cheeseman as Eq. 3.7 in Khoury & Gillett[2].

$$C_{DVe} = \left(\left(0.172 \sqrt[3]{(l/d)_e} + \left(\frac{0.252}{(l/d)_e^{1.2}} \right) + \left(\frac{1.032}{(l/d)_e^{2.7}} \right) \right) \right) / Re^{1/6} \quad (7)$$

Assuming that the hull drag comprises a fixed percentage of the total drag, the drag coefficient for the airship is estimated as

$$C_{DV} = C_{DV e} / k_D \quad (8)$$

Based on the drag breakdown of three airships reported by Cheeseman in Khoury & Gillett[2], an average value of k_D was taken as 0.5243.

The total drag at cruise is calculated using

$$D = C_{DV} \tfrac{1}{2} \rho_{a\,cr} V_{cr}^2 (V_e)^{2/3} \quad (9)$$

Propulsion sub-module
Power required to overcome drag during cruise is calculated by

$$P_{cr} = (D\, V_{cr}) / \eta_{prop} \quad (10)$$

The total installed power at sea-level static conditions is then estimated as

$$P_{inst} = P_{cr} (1 + p_{offtake}) / k_{alt} \quad (11)$$

The fuel weight can then be estimated using

$$W_{fuel} = (R/ V_{cr}) \text{ sfc } P_{cr} (1 + p_{offtake}) \quad (12)$$

Weight Estimation sub-module
This sub-module estimates the weight of each major system and sub-system of an airship, viz. Envelope, tail, equipped gondola and other sub-systems, thus leading to the estimation of the empty weight.

Gondola volume estimation The volume of gondola is required to estimate its weight. It is reasoned that gondola volume will be proportional to the payload which itself will be proportional to the envelope volume. The gondola volume ratio i.e. ratio of apparent volume of gondola (length times breadth times height) to the envelope volume was obtained for 21 airships, and the average value was found to be 0.007. Since most airship gondola are rounded at the front and back for improved aerodynamic characteristics, the gondola volume is assumed to be lesser than the apparent volume by a factor of 1.4. Hence the gondola volume to envelope volume ratio is taken to be 0.005.

Component weight breakdown Craig has provided a list of factors in Khoury & Gillett[2], which when multiplied with a specific reference parameter of the airship (such as envelope surface area, or volume) estimate the weight of various components**.** For instance, the weight of envelope fabric, including allowances for seams, patches, etc. varies from 0.35 kg/m^2 to 0.52 kg/m^2 of envelope surface area, depending on envelope volume.

The formulae for weight breakdown that are used in the methodology are listed in Table 4.

Sub-System	Component	Factor	Reference Parameter
Envelope	W_b	0.2	S_b
	W_{air}	0.025	W_e
	W_{cat}	0.115	W_e
	W_{pat}	0.035	W_e
	W_{sus}	0.012	V_e
	W_n	0.021	V_e
Tail	W_{fin}	2.05	S_{fin}
	W_{rig}	0.0475	W_{fin}
Equipped Gondola and sub-systems	W_{lg}	0.008	V_e
	W_{con}	0.46	$(V_e)^{2/3}$
	$W_{e\&i}$	0.037	V_e
	W_{gon}	10.75	V_{gon}
	W_{crew}	77	N_p
	W_{misc}	0.011	V_e

Table 4 Component weight breakdown formulae

Modeling the effect of design features and options

The selection of a particular design feature or option has a direct effect on some of the formulae and parameter values, as discussed below.

The choice of engine type (Diesel or Petrol) affects the engine specific fuel consumption and weight per unit power. These parameters were taken as 0.46 lb/(HP-hr) and 0.85 kg/HP for Petrol engines and 0.37 lb/(HP-hr) and 1.025 kg/HP for Diesel engines, respectively, which are the average of the values suggested by Cheeseman in Khoury & Gillett[2].

The choice of normally aspirated v/s supercharged engine affects the value of the power lapse factor with altitude (k_{alt}), which, for normally aspirated piston-prop engines was estimated using the following formula suggested by Raymer[5]. For supercharged engines, k_{alt} is assumed to be unity.

$$k_{alt} = \sigma_{crH} - \left(\frac{(1 - \sigma_{crH})}{7.55} \right) \tag{13}$$

The use of ducted propeller leads to improved η_p, lower noise levels and higher operational safety near ground, at the cost of increase in weight and complexity. Stinton[6] has plotted the variation of η_p of propellers and ducted fans with airspeed. The mean values of η_p for un-ducted and ducted fan in the speed range of 70 to 90 kmph were taken as 0.53 and 0.76, respectively. The weight of the un-ducted propeller, ducted propeller and the duct was taken as 0.175, 0.125 and 0.375 kg /HP, respectively, which are the mean of the range for these values suggested by Craig in Khoury & Gillett[2].

An integral ballonet has one surface common with the envelope, hence it has lower surface area, leading to slightly lower weight, but it is more difficult to fabricate and repair.

The choice of fin layout affects the number of fins, the total surface area and hence the weight of the fin structure. In the Cross type layout, four fins are assumed, while in Plus type layout, three fins are assumed.

Provision of thrust vectoring leads to an additional weight penalty, which is estimated as 14% of the weight of the vectored mass. This value is the mean of the range suggested by Craig in Khoury & Gillett[2].

A simple transmission system with no separate accessory gearbox was assumed to weigh 0.17 kg/HP installed power. On the other hand, a complex system including accessory drives was assumed to weigh 0.275 kg/HP of installed power. These figures are the mean of the ranges suggested by Craig in Khoury & Gillett[2] for an inboard engine and outboard propeller configuration.

VALIDATION OF MASS ESTIMATION

A comparison of estimated and actual weights for Sentinel 1000, for which a detailed weight breakdown was listed in Netherclift[7], is shown in Table 5. It can be seen that except for the fins, the error in weight estimation is within 10%.

Component	Estimated values	Quoted values	% Diff.
$\mathbf{W_e}$	2098.4	2061	2
$\mathbf{W_{fin}}$	762.7	960	-21
$\mathbf{W_{gon} + W_{lg}}$	748.2 + 82.4	910	-9
$\mathbf{W_{eng} + W_{fuel} + W_{tr} + W_{vec}}$	635.8	622.7	2
$\mathbf{W_{prop} + W_{duct}}$	220.8	356	-9
$\mathbf{W_{con}}$	236.4	249.6	-5
$\mathbf{W_{e\&i}}$	418.9	438	-4
$\mathbf{W_{misc}}$	124.6	128.7	-3
$\mathbf{W_{empty}}$	**5328.2**	**5726**	-7

Table 5. Comparison of weight breakdown for Sentinel-1000 with values quoted by Netherclift[7]

Some details of component weights were also available for Ulita's UM-10 airship in Berger[8], and in the performance manual[9] of US-LTA 185 M airship. A comparison of the estimated values with the quoted values is listed in Table 6a and Table 6b. Here again, the estimated weights compare well with the quoted values, except for the fin weight.

Ulita's UM 10 Airship			
Component	**Estimated values**	**Quoted values**	**% Diff.**
W_e	136.3	135.6	0.5
W_{fin}	34.5	29.8	16
W_{gon}	121.8	120.0	1.5
W_{empty}	292.6	291.0	0.6

Table 6a. Weight breakdown of Ulita's UM-10 airship

US LTA 185 M Airship			
Component	**Estimated values**	**Quoted values**	**% Diff.**
W_e	1194	1369	-13
W_{fin}	473	420	13
W_{gon}	1125	1039	4
W_{empty}	2792	2870	-3

Table 6b. Weight breakdown of US-LTA 185M airship

The comparison between calculated empty weights for four other airships with the values quoted in Jane's[10] is shown in Table 7. It is seen that the methodology predicts the empty weight within ± 12%.

Airship	**W_e (Estimated)**	**W_e (Quoted)**	**% Diff.**
PD 300	1664	1500	11
MD 900	5193	4680	11
Skyship 600	3601	3331	8
A 150/S 42	2524	2866	-12

Table 7 Comparison of estimated and quoted empty weight for four airships

RESULTS

The methodology was applied to obtain the baseline specifications of two airships viz., *DEMO* and *PAXCARGO*, for operation over hot and high conditions. For *PAXCARGO* airship, the methodology was applied in the *design* mode to obtain the envelope volume required for a specified payload capacity of 1500 kg. For the *DEMO* airship, the payload capacity was determined by applying the methodology in the *analysis* mode for a specified envelope volume of 1000 m^3. Both the airships were assumed to have a twin-engined configuration with thrust vectoring, and Helium purity level of 95%.

The key input parameters, and the baseline specifications obtained through the methodology are listed in Table 8. The general layout of DEMO and PAXCARGO airships, as shown in Figure 5 & 6.

Parameter	***DEMO* Airship**	***PAXCARGO* Airship**
Key Input Parameters		
Payload Weight	to be calculated	1500 kg
Envelope volume	1000 m^3	to be calculated
Temperature deviation from ISA	+15^O C	+15^O C
Minimum altitude	2000 m	2000 m
Cruising altitude	3500 m	3500 m
Pressure altitude	4000 m	4000 m
Cruising speed	78 kmph	92 kmph
Range	100 km	500 km
Envelope *l/d* ratio	3.05	4.0
Engine Type	Petrol	Diesel
Engine Charging	Normally Aspirated	Supercharged
Baseline Specifications		
Payload weight	73.2 kg	Known
Envelope volume	Known	11177 m^3
Ballonet volume	226 m^3	2531 m^3
Max. speed	86 kmph	102 kmph
Installed power	80 HP	300 HP
Fuel weight	9.96 kg	218.4 kg
Empty weight	535 kg	5036.7 kg
Lift at Pressure altitude	618.1 kg	6908 kg

Table 8: Input parameters and baseline specifications of *DEMO* and *PAXCARGO* airship

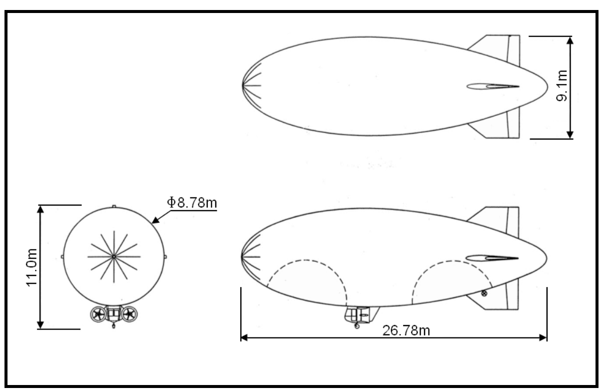

Fig. 5. General layout of *DEMO* airship

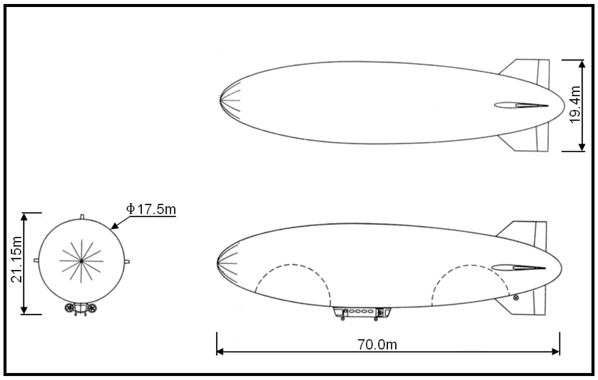

Fig. 6. General Layout of *PAXCARGO* airship

SENSITIVITY STUDIES

Some sensitivity studies were carried out for the *DEMO* airship to investigate the effect of various input parameters on W_{Pay}. The results of these sensitivity studies are discussed below.

Effect of change in H_{max} and Δ_{ISA} on W_{pay}

The reduction in payload capacity with increase in pressure altitude and ambient temperature is plotted in Figure 7 and 8, respectively.

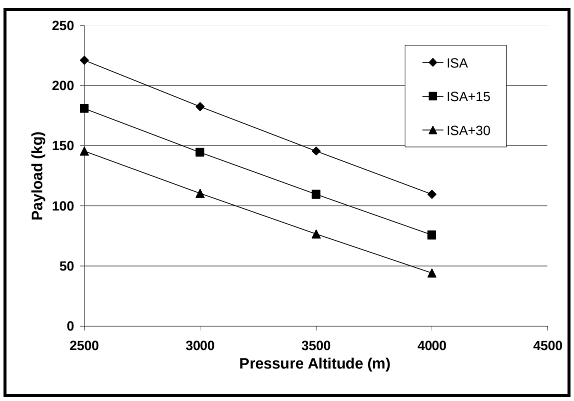

Fig.7 Sensitivity of W_{pay} to H_{max} at various $\underline{\Delta_{ISA}}$

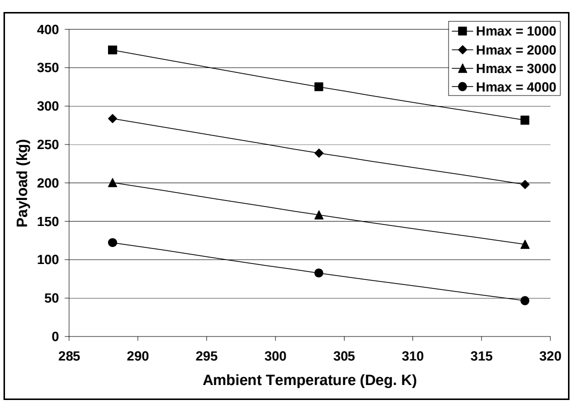

Fig.8 Sensitivity of W_{pay} to $\underline{\Delta_{ISA}}$ at various H_{max}

It can be seen that the payload capacity reduces linearly with increase in any of these parameters, keeping the other constant.

Effect of loss of Helium purity on W_{Pay}

The reduction in net Lift under ISA conditions with loss of Helium purity is shown in Fig. 9. It can be seen that a 1% decrease in Helium purity results in a 8.6% loss in payload capacity, which is quite substantial.

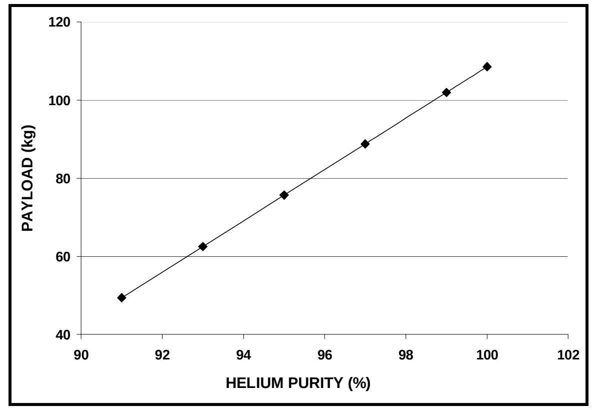

Fig 9. Sensitivity of W_{pay} to Helium prity (%)

Effect of change in $(l/d)_e$ on W_{pay} and V_{cr}

S_e and $C_{DV\ e}$ are affected by $(l/d)_e$ through Eq. 3 and 4, respectively. Fig. 10 depicts the effect of $(l/d)_e$ on the payload and cruise velocity. As expected, the cruise speed is seen to increase with increase in $(l/d)_e$, but a saturation limit is reached at a value of around 4.0. At V_{cr} of 82.5 kmph, W_{pay} is seen at an $(l/d)_e$ of 3.0.

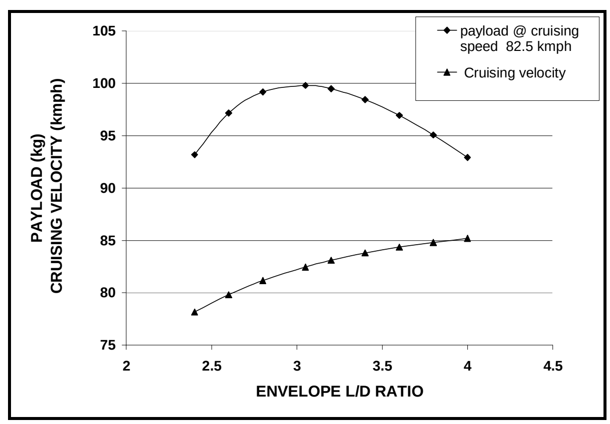

Fig. 10. Sensitivity of W_{pay} and V_{cr} on $(l/d)_e$

Change in W_{pay} with R for various engine types

As per the current formulation, a diesel engine has a lower specific fuel consumption compared to a petrol engine, but higher specific weight per unit power. The payload was calculated under the identical operating conditions for a few values of Range for both the engine types. The result is plotted as Fig. 11. It is seen that for lower values of Range (upto about 330 km), a petrol engine results in larger payload compared to a diesel engine. However, the rate of decrease in payload capacity with increase in Range is less for diesel engine, compared to a petrol engine.

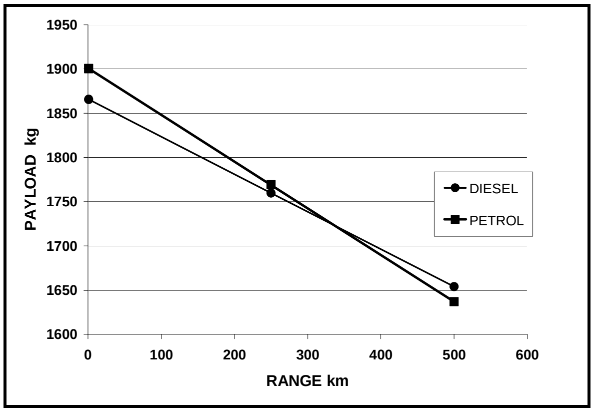

Fig. 11 Sensitivity of W_{pay} to Range for Diesel and Petrol Engines

Effect of V_{cr} on W_{Pay}

It is clear that if the design cruise speed is increased, the installed power will also increase and accordingly the engine weight will also increase. For a fixed envelope size (i.e. a fixed lift), this will lead to a reduction in the payload. This relationship is shown in Fig. 12. It is seen that if the installed engine power is increased, the reduction in payload capacity is much larger compared to the increase in cruise speed, and vice versa.

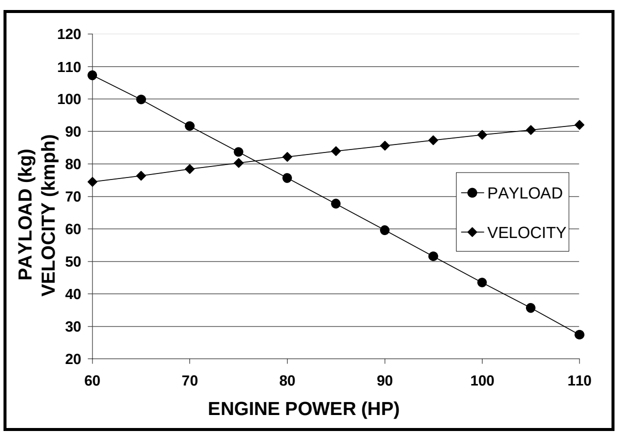

Fig. 12 Sensitivity of W_{pay} and V_{cr} to Engine Power

Difference between Ducted and Un-Ducted Propellers.

In order to decide whether a propeller installed should be ducted or un-ducted, the payload for two cases was calculated, assuming that both the propulsive systems develop the same thrust. The comparative values of some salient parameter are shown in Table 9. The ducted propeller results in lower propulsion group weight, which translates into 25% higher payload.

Parameter	Un-ducted	Ducted	% Diff
P_{inst}	105.6	73.4	-30.5
$W_{eng} + W_{prop} + W_{duct}$	126.6	108.6	-14.2
W_{empty}	535.1	517.2	-3.4
W_{fuel}	13.2	9.2	-30.5
W_{pay}	88.1	110.1	24.9

Table 9. Comparative analysis of Ducted and Un-Ducted Propeller

Conclusions

The methodology presented in this paper is a useful tool during the conceptual design studies of a non-rigid airship. It can be used to arrive at the baseline specifications of an airship to be designed to meet specific operational requirements. It can also be used to evaluate the capability of an existing airship to meet these requirements. The most useful application of the methodology, however, would be to determine the sensitivity of operational requirements such as payload, pressure altitude, ambient temperature, cruising speed on the configuration related parameters such as Helium purity level and envelope length-diameter ratio on the payload available or envelope volume required. This can help identify the requirements that drive the design, and to investigate several "what-if" scenarios.

Though several empirical formulae and statistical data of existing airships have been used in the methodology, the component weights and empty weight are within 15% of quoted values, which is quite reasonable in conceptual design phase. The formulation of the methodology is open ended, so it can be continuously upgraded and fine-tuned as more accurate information becomes available. It can also be adopted for carrying out MDO (multi-disciplinary design optimization) of an airship system, for instance to determine the optimum combination of design parameters and options that correspond to highest payload available.

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