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VARIOUS OPTIMISATION METHODS FOR PRELIMINARY COST AND MASS DISTRIBUTION ASSESSMENT FOR MULTISTAGE ROCKET VEHICLES.

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Abstract:

Preliminary staging studies of multi-stage space launchers are described. Both propellant and thrust scaling factors are used, and also cost parameters for propellant, propellant scaling units and thrust scaling units. The general minimum cost study, including reusable stage(s), turns out to be a generalisation of the optimisation method of the payload ratio, for specified mission requirement. Both studies lead to a velocity increment distribution between the stages, based upon optimum initial acceleration for each stage. The similarity between this analysis and that developed by Vertrégt, Hall and Zambelli, and others is pointed out. Penalties for non-optimum solutions are also considered.

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Nomenclature

a	=	vehicle absolute acceleration, m/s^2.
c	=	effective exhaust velocity, m/s.
C	=	cost criterion $(\lambda_P + \lambda_T T)/\lambda_E$
$\bar{D}$	=	mean drag over flight N.
E	=	engine scaling constant $M_E/\dot{m}_P$ seconds.
$\bar{F}$	=	mean thrust over flight N.
G	=	mean effective component of gravitational field opposing vehicle acceleration, m/s^2.
g	=	local gravitational acceleration.
L	=	stage payload mass ratio M_L/M_α
M	=	mass, Kgm.
$\dot{m}$	=	dM/dt, Kgm/s.
P	=	stage propellant mass ratio M_P/M_α
R	=	reactor scaling constant $M_R/\frac{1}{2}\dot{m}_P c^2$, s^3/m^2
T	=	"tank" scaling constant M_T/M_P
v	=	velocity, m/s.
Δv	=	achieved velocity increment $v_\omega - v_\alpha$, m/s.
X	=	velocity loss factor due to drag $(1 - \bar{D}/\bar{F})$
λ	=	stage specific cost per unit mass of payload, £/Kgm.
λ_E	=	specific cost per unit mass of engine, £/Kgm.
λ_{ER}	=	specific cost per unit mass of reactor + engine, £/Kgm.
λ_P	=	specific cost, propellant, £/Kgm.
λ_T	=	specific cost, propellant container, £/Kgm.

Suffices

E	=	engine or solid propellant nozzle
L	=	stage payload
P	=	propellant
T	=	tank or solid propellant case
R	=	reactor
α	=	stage state at launch
ω	=	stage state at all burnt

Specific Cost Standard Exchange Rate (Rounded Values)

£1/Kgm. = $ 1.25/lbm = 9 shilling/lbm.

$ 1/lbm = £0.8/lbm.