Power Cable Mass Estimation for Electric Aircraft Propulsion

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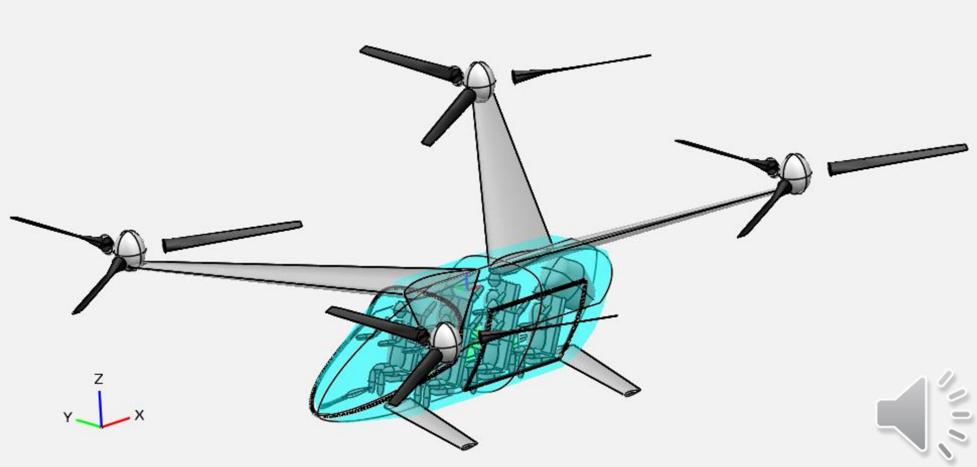
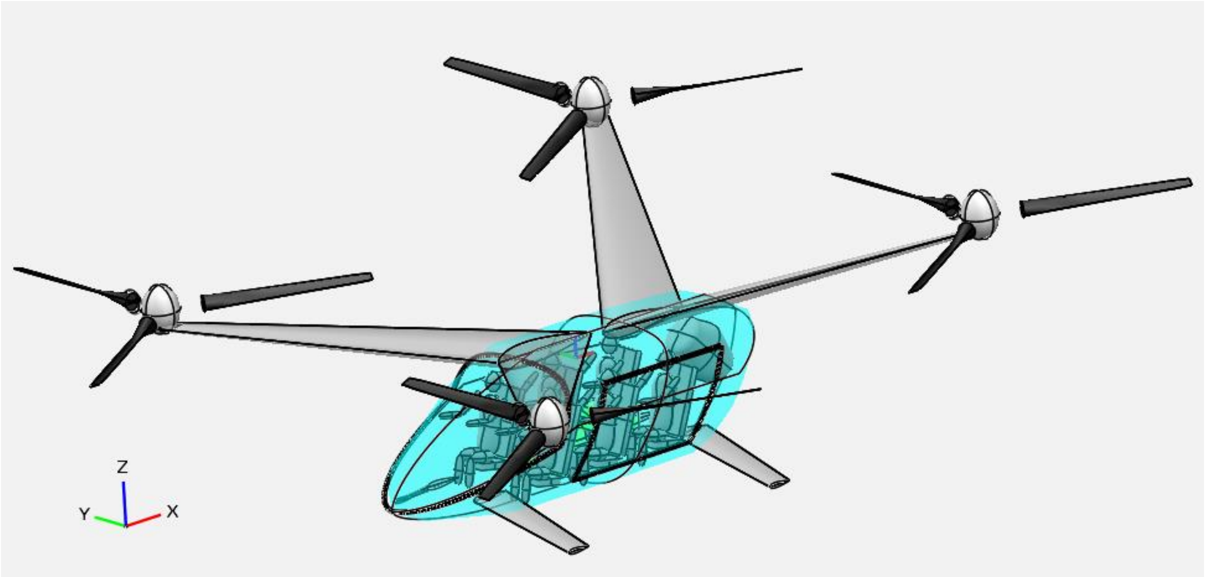
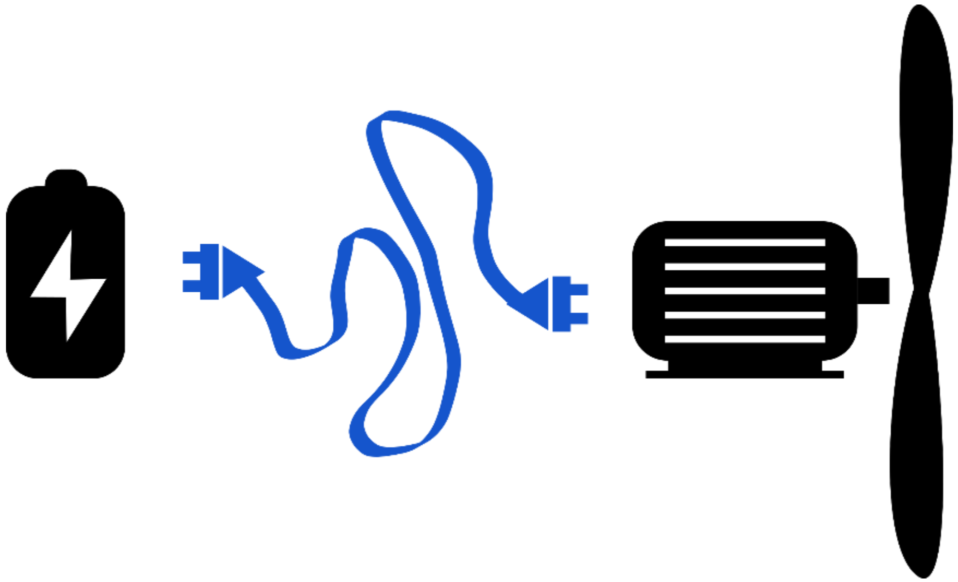
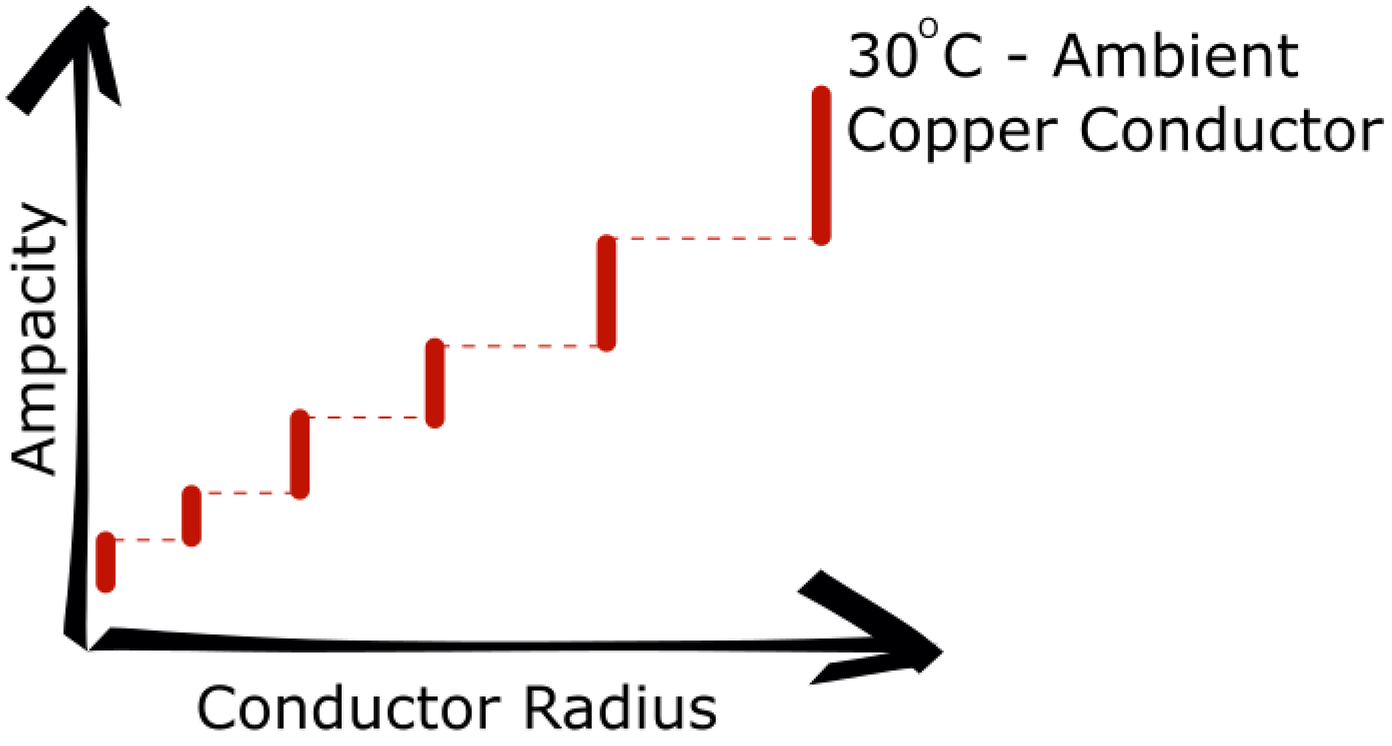


Cable Sizing and Mass Estimation is an Essential Part of Electric Aircraft Propulsion





We need physics based cable models that can be subject to standard optimization techniques and produce a continuous solution space



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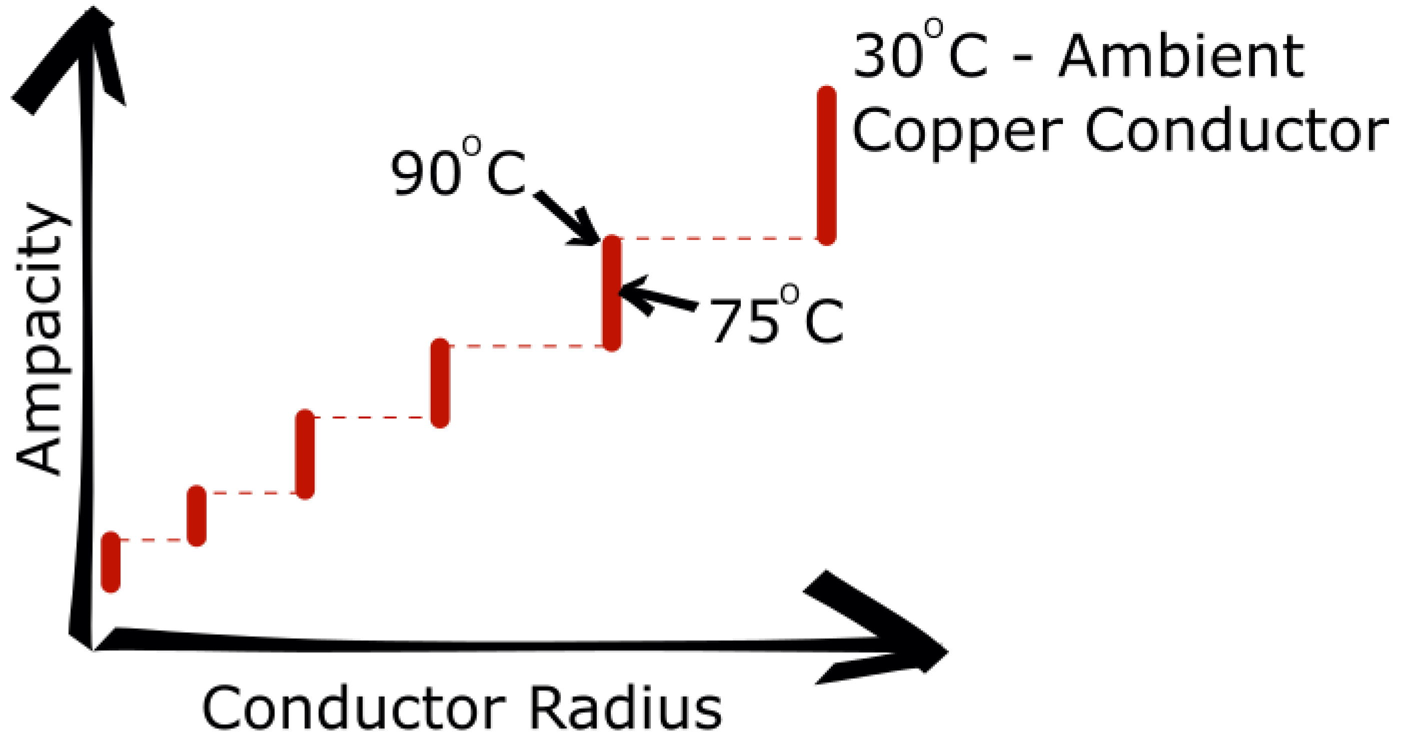

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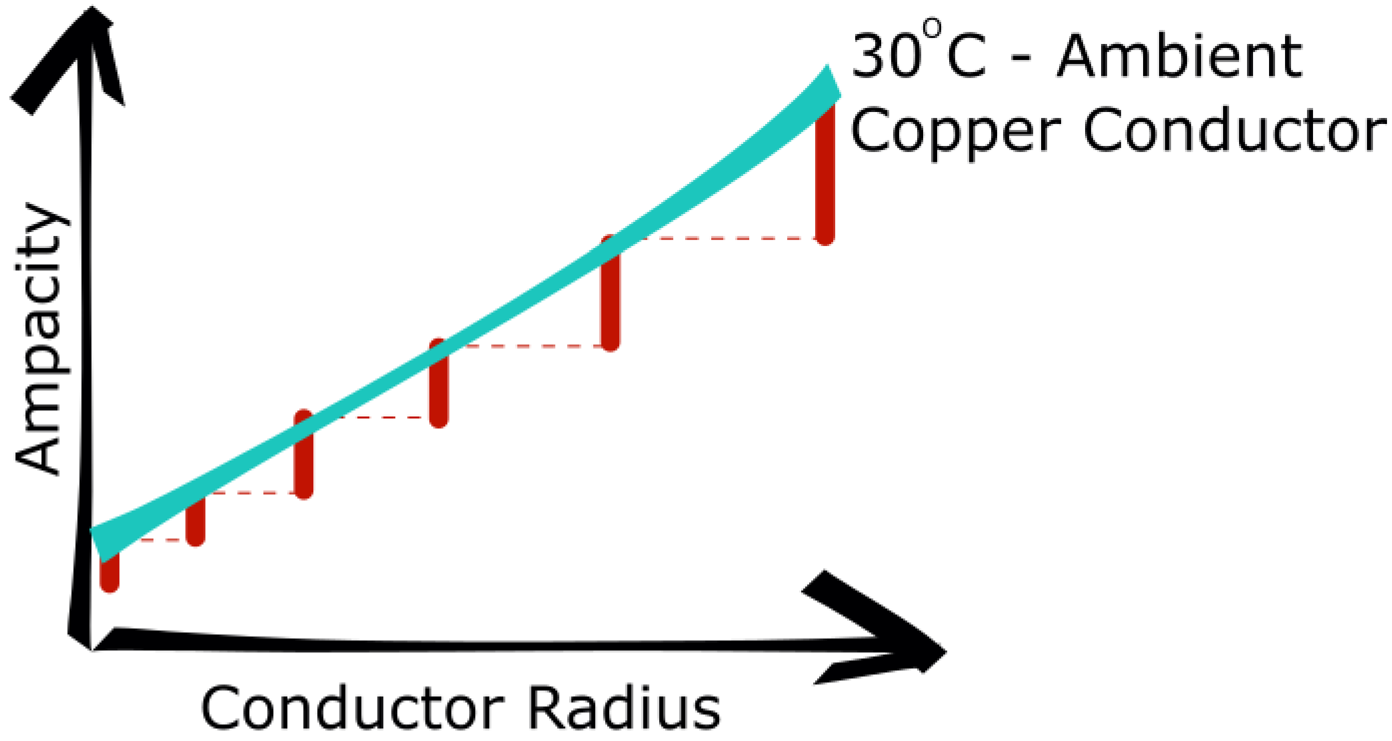

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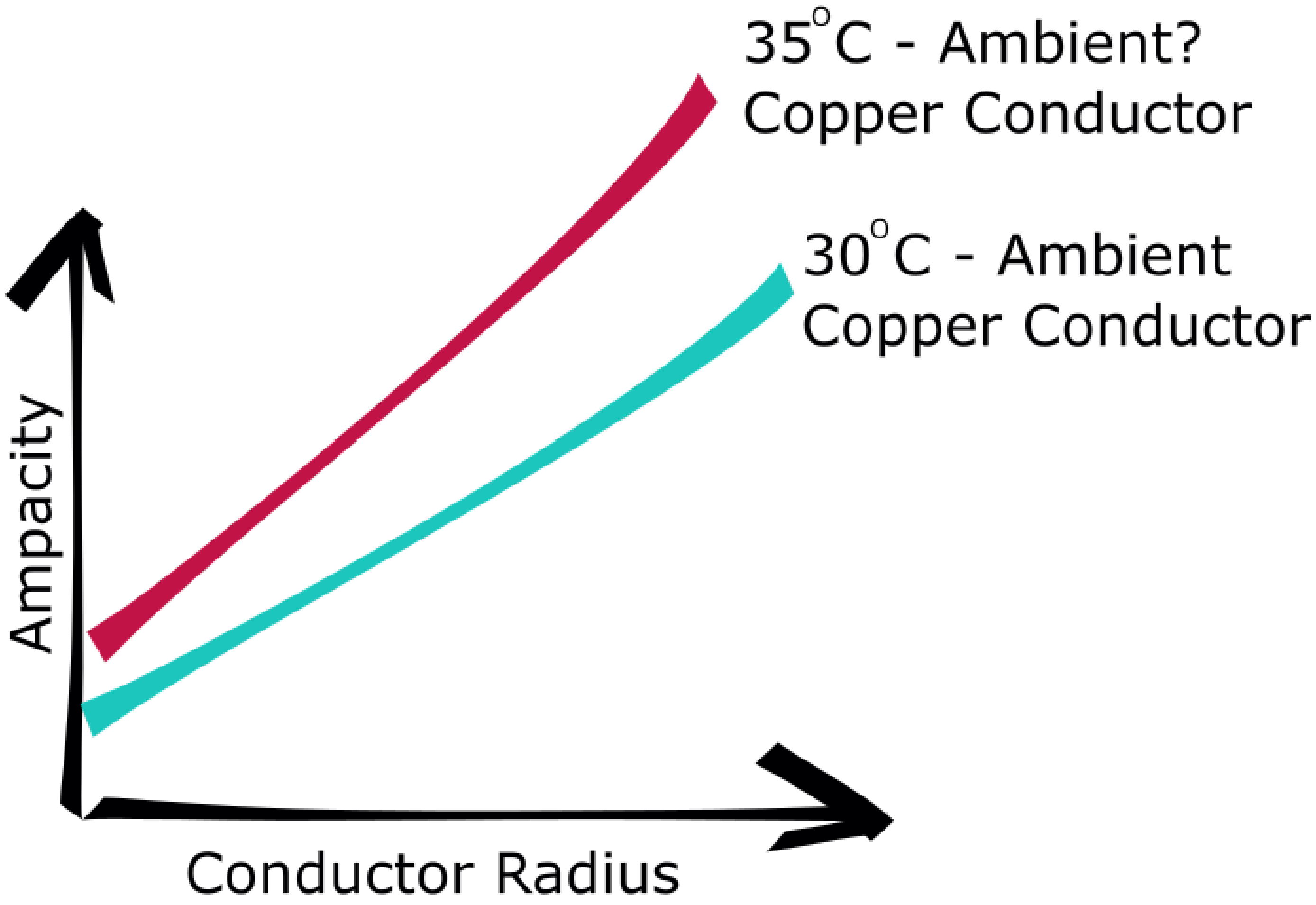

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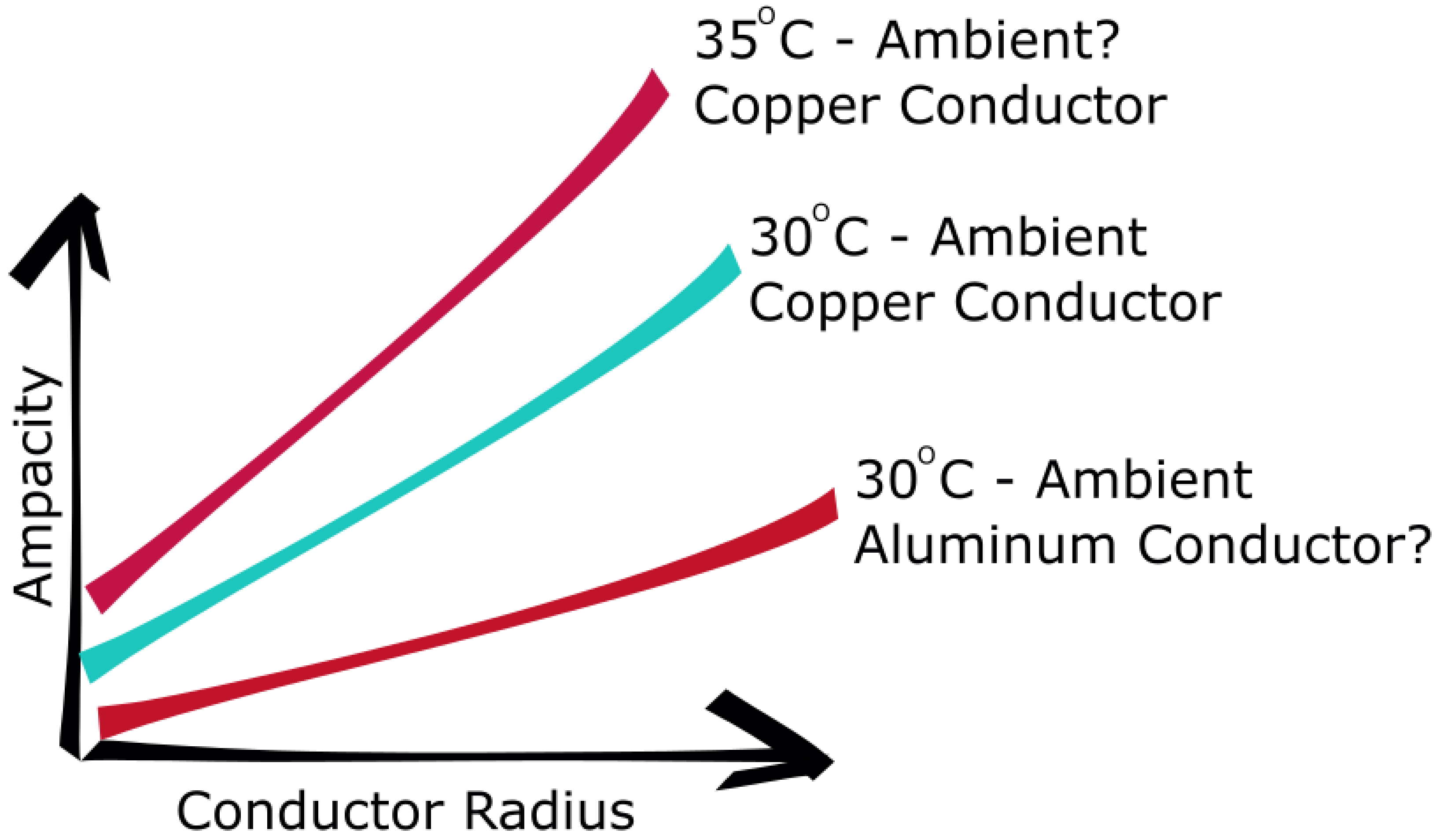


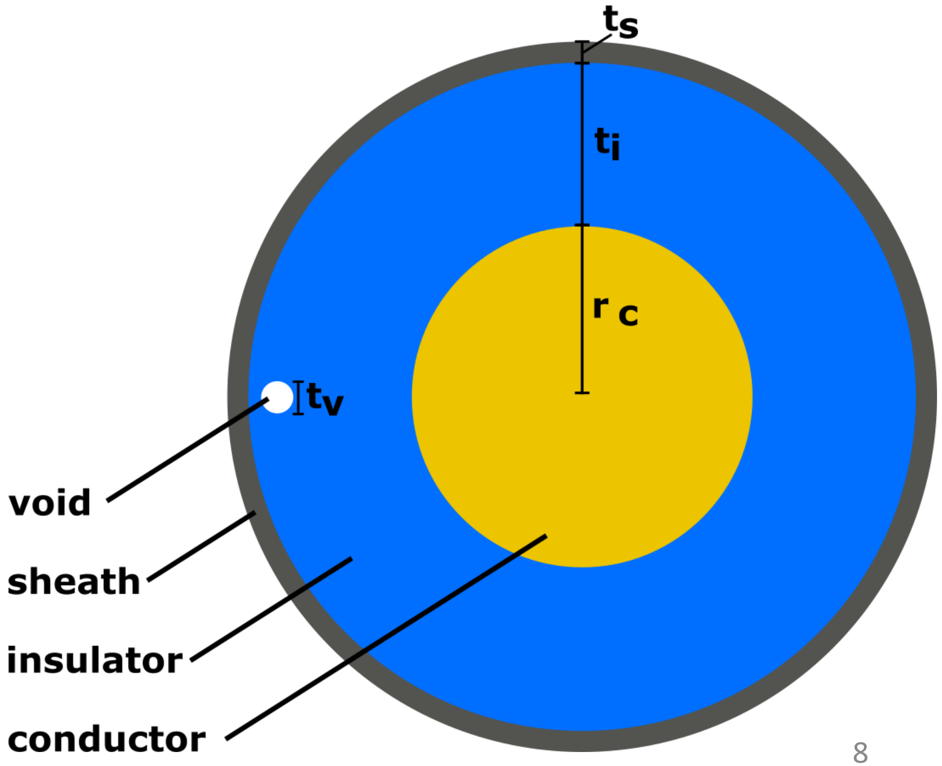
A cable model was constructed that considers simple physics-based thermal, material, and electrical aspects

$$t_i = f(\in, V_{max}, t_v, \alpha, r_c)$$

$$\text{cable mass} = f(t_i, r_c, \rho_i t_s, \rho_s)$$

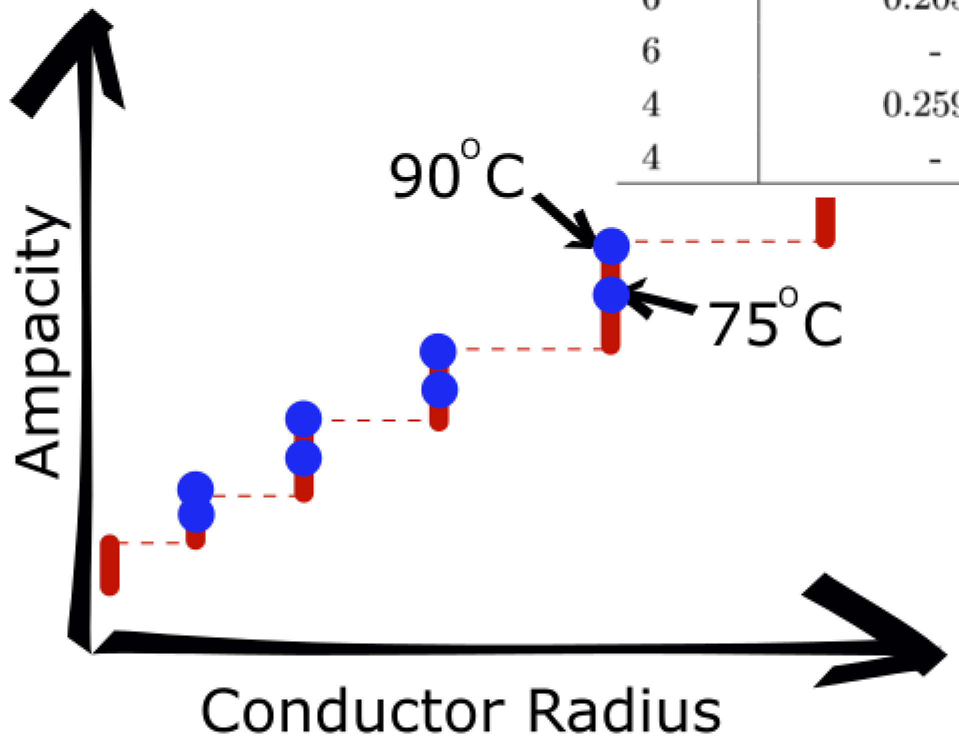
$$T_{steady\_state} = f(I, R_c, t_i, r_c, h, T_\infty)$$

$$\frac{dT_{cable}}{dt} = f(Q_c, Q_\infty, HC_C, HC_i)$$



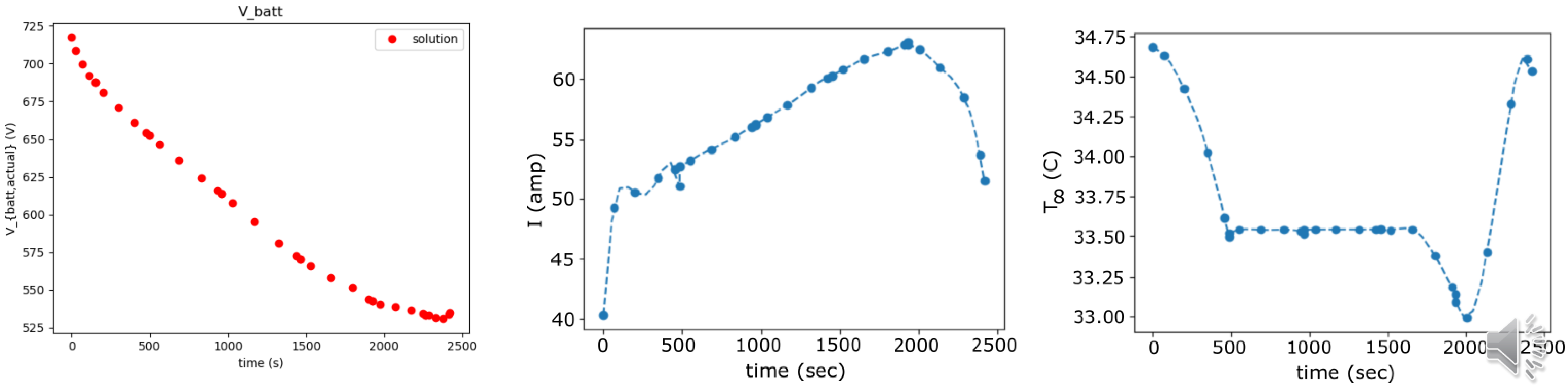
The model was tuned to match published data

AWG	Conductor Radius (cm)	Ampacity (A)	Ref Temp (C)	Transient Temp (C)	Steady State Temp (C)	Ref $\bar{m}_{tot}$ (kg/m)	Calc $\bar{m}_{tot}$ (kg/m)
10	0.129	50	75	77	77	0.086	0.088
10	-	55	90	89	89	-	-
8	0.1632	70	75	75	74	0.140	0.143
8	-	80	90	92	92	-	-
6	0.2057	95	75	78	77	0.1949	0.196
6	-	105	90	90	91	-	-
4	0.2595	125	75	76	76	0.2694	0.279
4	-	140	90	90	91	-	-



We applied a known power demand profile and performed optimizations of cable mass using two methods: steady-state and transient analysis

- Temperature profile over mission
- Amp profile over the mission
- Highlighting how steady-state selects peak amps and transient uses amps throughout the mission

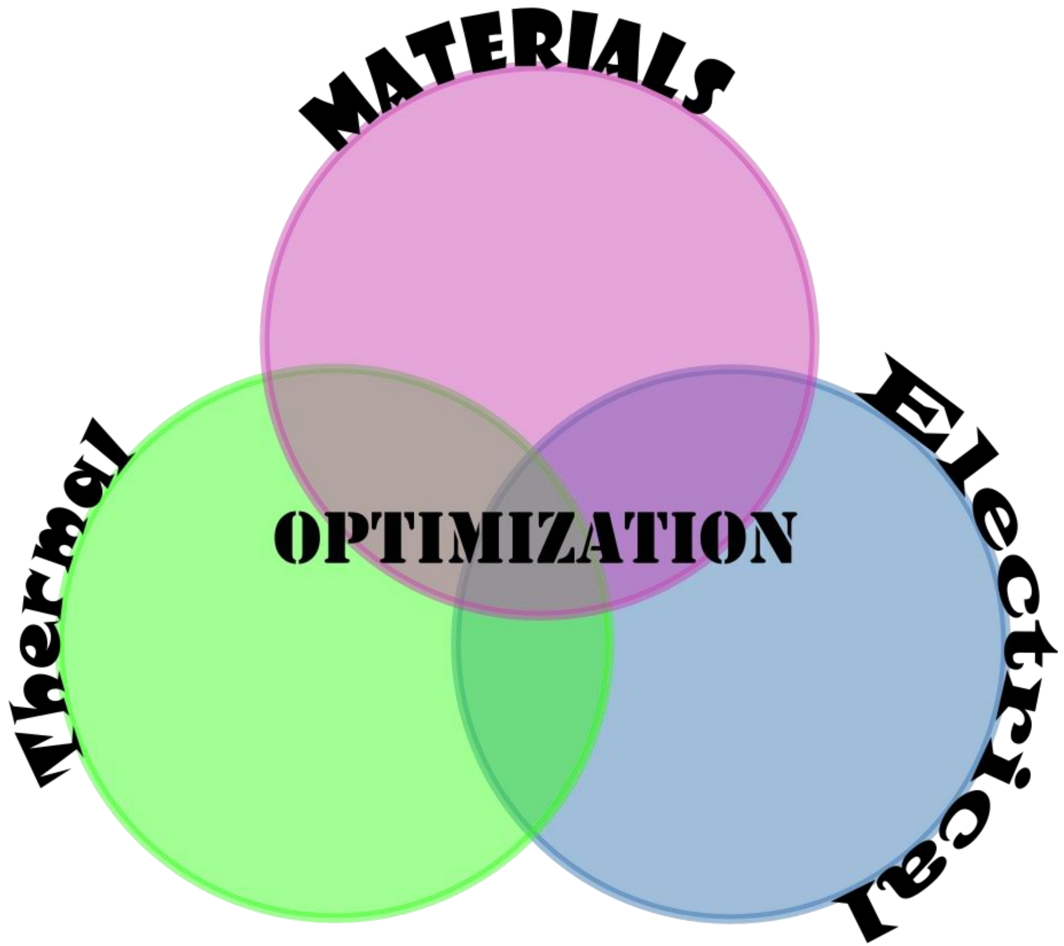


Results demonstrated successful optimizations in both steady-state and transient analysis.

Table 4: Cable mass and temperature results by design method and *temperature constraint.

Design Method	Optimization Method	Copper (%) (0 = Al)	Radius (cm) Conductor	Max Temp (C) Estimated (Eq. 29)	Max Temp (C) Mission Max (Eq. 27)	Mass (kg)
COTS	None	100	0.163	73	67	12.55
-	None	0	0.2057	68	62	9.96
Steady State	Radius	100	0.143	90*	85	9.92
-	Material	32	0.163	90*	85	8.68
-	Combined	0	0.172	90*	85	7.54
Transient	Radius	100	0.138	95	90*	9.50
-	Material	10	0.163	95	90*	7.66
-	Combined	0	0.166	95	90*	7.29

These methods lay the groundwork for thermal, material, electrical, and optimization experts to collaborate and build more detailed models

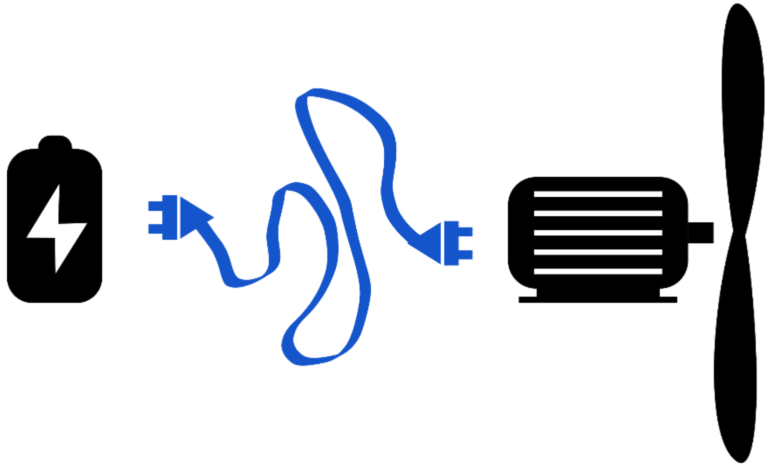


Thanks and Questions

- This work was supported by Transformational Tools and Technologies (TTT) project

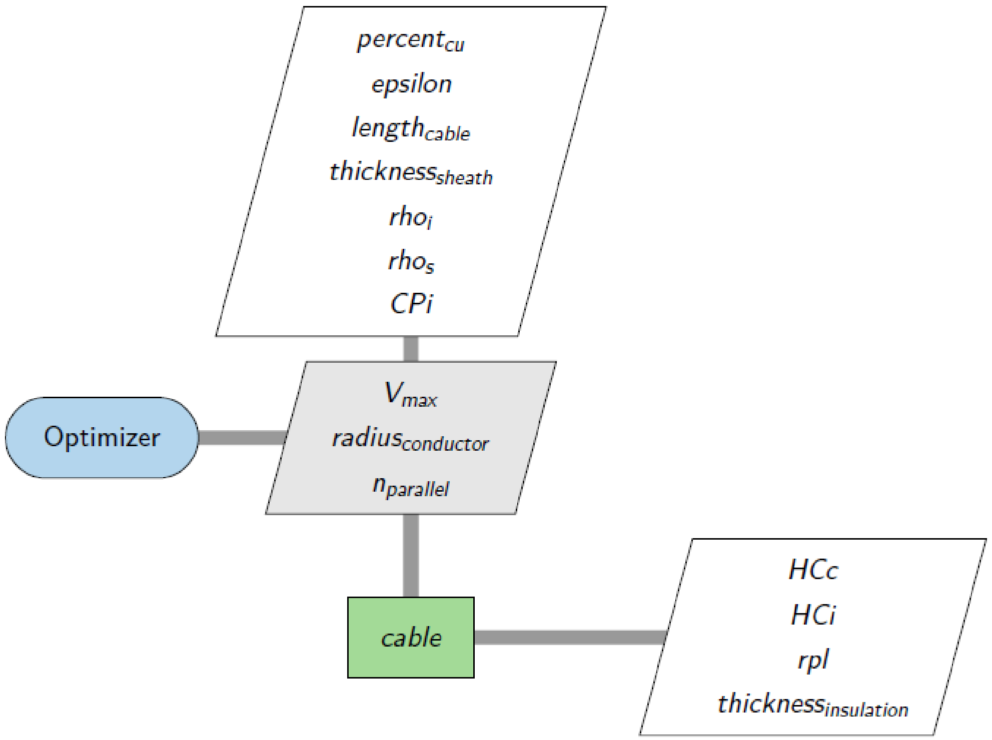
- Questions on this topic can be sent via email to:

  - EARETSKI@MAIL.NASA.GOV



Extended Design Structure Matrix (XDSM) Backup

Static Analysis



Dynamic Analysis