Certification Challenges for Batteries in Electric Aviation

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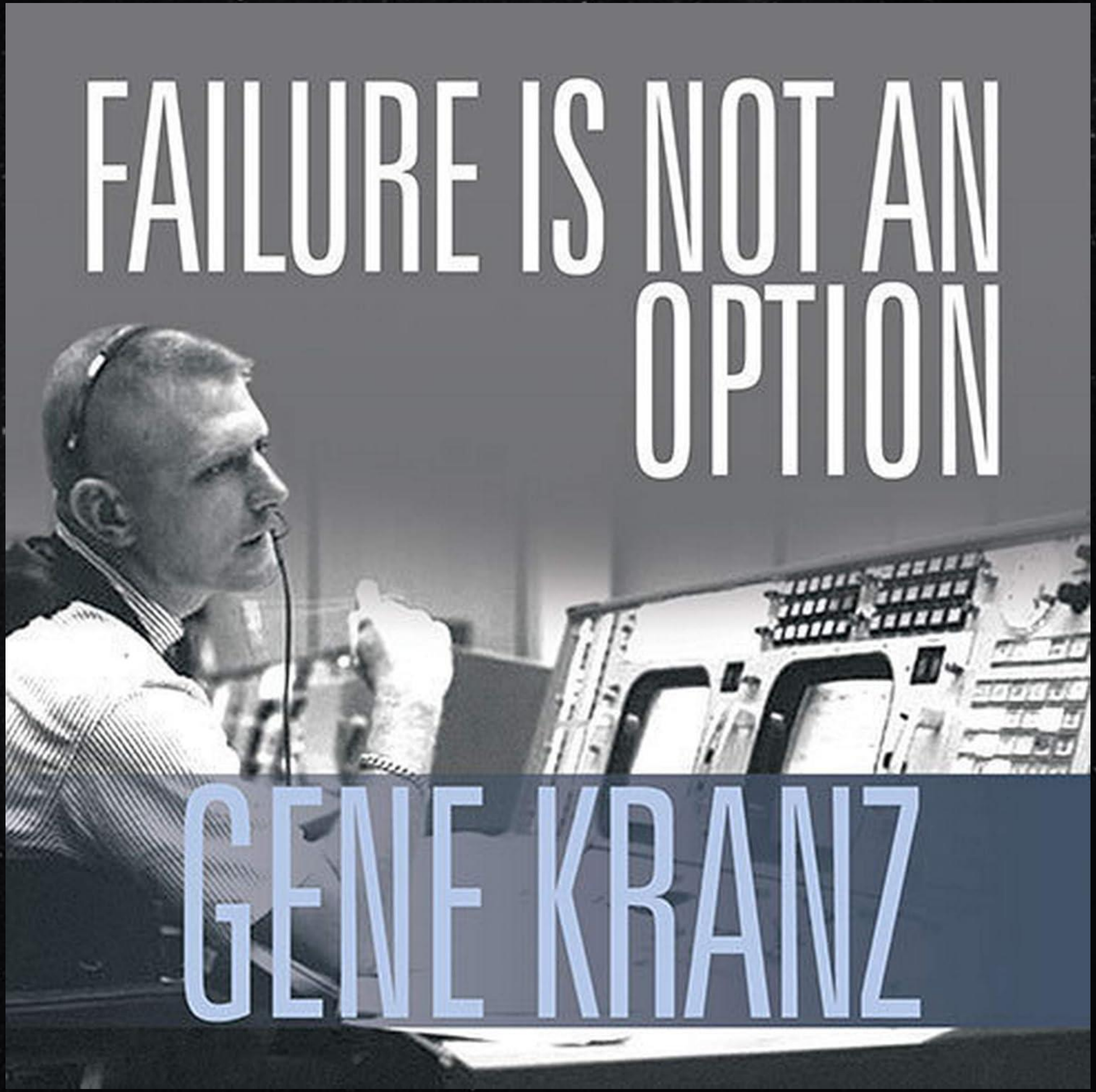
Electric Aviation Challenges

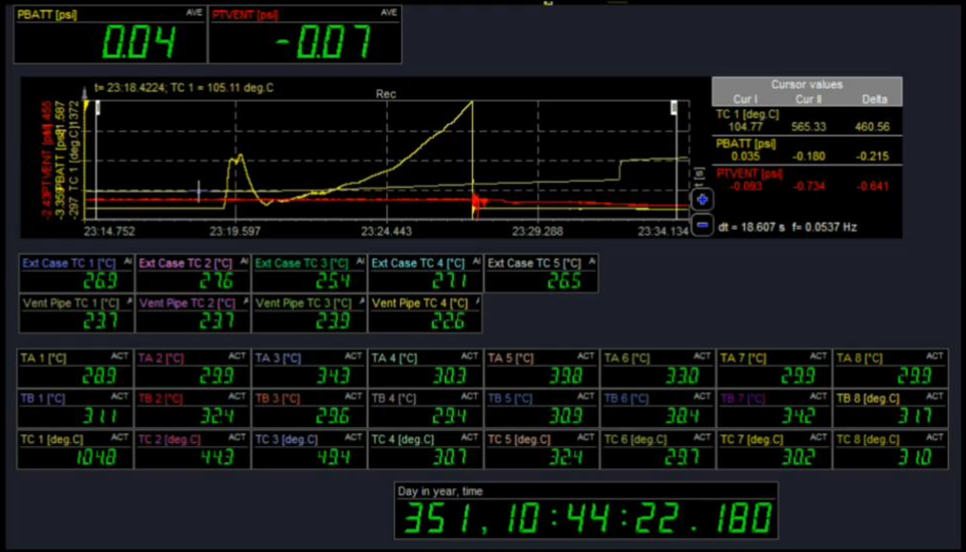
Power and Energy vs Mass

Validating Safety

Commercialization



X-57 Video



PBATT [psi] AVE 0.04
PTVENT [psi] AVE -0.07
t= 23:18.4224; TC 1 = 105.11 deg.C
Rec
Cursor values
Cur I Cur II Delta
TC 1 [deg.C] 104.77 565.33 460.56
PBATT [psi] 0.035 -0.180 -0.215
PTVENT [psi] -0.093 -0.734 -0.641
dt = 18.607 s f= 0.0537 Hz
Ext Case TC 1 [°C] 26.9
Ext Case TC 2 [°C] 27.6
Ext Case TC 3 [°C] 25.4
Ext Case TC 4 [°C] 27.1
Ext Case TC 5 [°C] 26.5
Vent Pipe TC 1 [°C] 23.7
Vent Pipe TC 2 [°C] 23.7
Vent Pipe TC 3 [°C] 23.9
Vent Pipe TC 4 [°C] 22.6
TA 1 [°C] ACT 28.9
TA 2 [°C] ACT 29.9
TA 3 [°C] ACT 34.3
TA 4 [°C] ACT 30.3
TA 5 [°C] ACT 39.8
TA 6 [°C] ACT 33.0
TA 7 [°C] ACT 29.9
TA 8 [°C] ACT 29.9
TB 1 [°C] ACT 31.1
TB 2 [°C] ACT 32.4
TB 3 [°C] ACT 29.6
TB 4 [°C] ACT 29.4
TB 5 [°C] ACT 30.9
TB 6 [°C] ACT 38.4
TB 7 [°C] ACT 34.2
TB 8 [deg.C] ACT 31.7
TC 1 [deg.C] ACT 104.8
TC 2 [deg.C] ACT 44.3
TC 3 [deg.C] ACT 49.4
TC 4 [deg.C] ACT 30.7
TC 5 [deg.C] ACT 32.4
TC 6 [deg.C] ACT 29.7
TC 7 [deg.C] ACT 30.2
TC 8 [deg.C] ACT 31.0
Day in year, time
351, 10:44:22.180

Fault Tolerance for Crewed Space Flight

No Single Failure can lead to Loss of Crew or Loss of Vehicle

- NASA philosophy of safety is fault tolerance
- For catastrophic hazards (including batteries) a minimum of two fault tolerance is required
  - Three independent controls to catastrophic hazards
  - Critical systems must maintain safe function even after one or more failures
  - Fail safe
- Redundant, independent, and dissimilar controls

Crewed Space Flight Requirements

- JSC 20793 Rev D, Crewed Space Vehicle Battery Safety Requirements contains the detailed design information for all batteries on crewed spacecraft, including vehicle, payload, and crew equipment batteries

1. External Cell Short
   - Improper battery design, operating errors or mishandling can all lead to a catastrophic hazard
   - Proper insulation, energized component separation, detection, FOD control, and tolerance to both high and low impedance shorts (smart short)
2. Internal Cell Short
   - Manufacturing defect, physical or electrical abuse can rapidly go into TR without any prior indication
   - Battery design and demonstrated to prevent cell-to-cell propagation
3. Overcharge
   - Charger protocols exceed current of voltage rating of the battery, imbalance of cells or strings in series
4. Over Discharge
   - A single over discharge event is generally not a catastrophic failure but recharging can lead to a TR
5. Thermal Extremes
   - Maintaining the battery within temperature limits is critical to both safety and life

Questions?

5 Design Driving Factors for Reducing Hazard Severity from a Single Cell Thermal Runaway (TR)

- **Prevent cell structural failures from directly impinging neighboring cells**
  - Without structural support most high energy density (>660 Wh/L) designs are very likely to experience side wall ruptures during TR
  - Battery should minimize constrictions on cell TR pressure relief
- **Provide adequate cell spacing and heat rejection**
  - Direct contact between cells nearly assures propagation
  - Spacing required is inversely proportional to effectiveness of heat dissipation path
- **Prevent circulating currents within a virtual cell or battery**
  - Initiating cell becomes an external short path to parallel cells generating significant heat which can lead to propagation
- **Protect the adjacent cells from the hot TR cell ejecta (solids, liquids, and gases)**
  - TR ejecta is electrically conductive and can cause circulating currents
- **Prevent flames and sparks from exiting the battery enclosure**
  - Provide tortuous path for the TR ejecta before hitting battery vent ports equipped flame arresting screens