Evaluation of Lithium Polymer Batteries

Evelyne Simon ESA/ESTEC

- Space applications
- Selection of cells
- Evaluation of 5 cell types

} Study by **SSTL** (**AEAT** as sub) under ESA contract

- Life testing

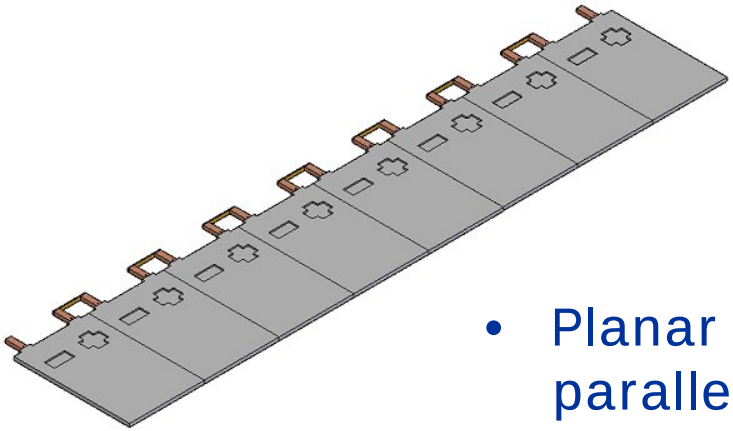
} ESA internal testing

Advantages of Geometric Flexibility (SSTL)

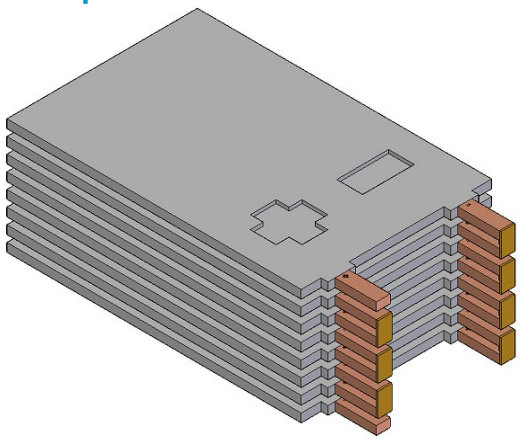
- Low Altitude mission
- Mechanical Shock Resistance
- Magnetic Cleanliness
- Bipolar cell for HV applications
- Mechanical housing sharing
- Dish antennas
- Propulsion systems
- Spin balancing
- …

Lithium Ion Polymer Battery

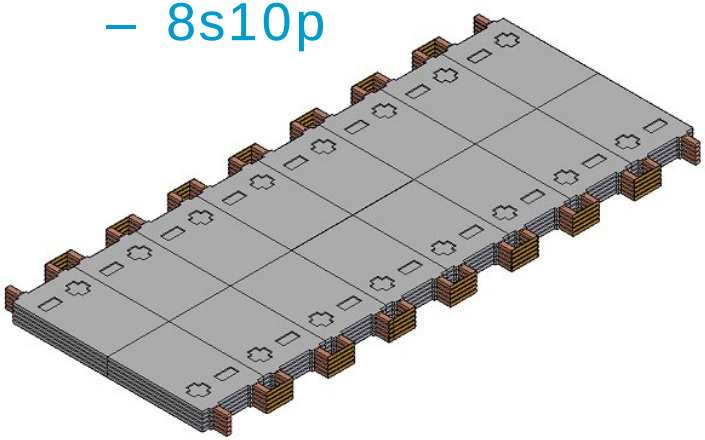
- Planar Battery Array
  - 8s1p



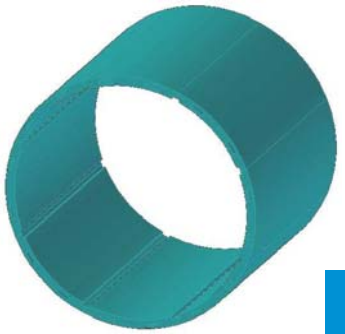
- Stacked Battery
  - 8s1p

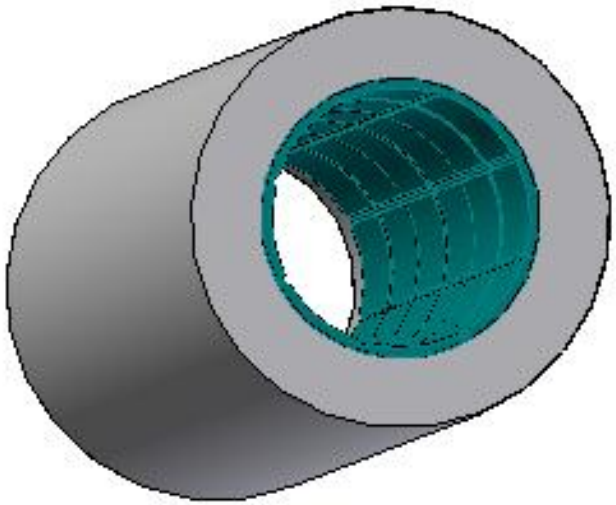


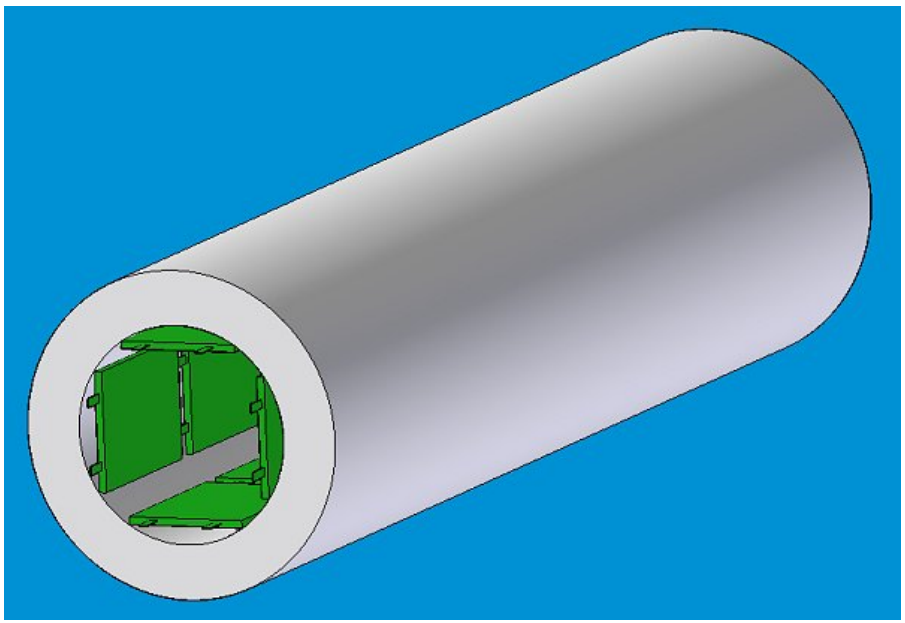
- Planar Battery Array, parallel strings
  - 8s10p



- Bespoke Shapes





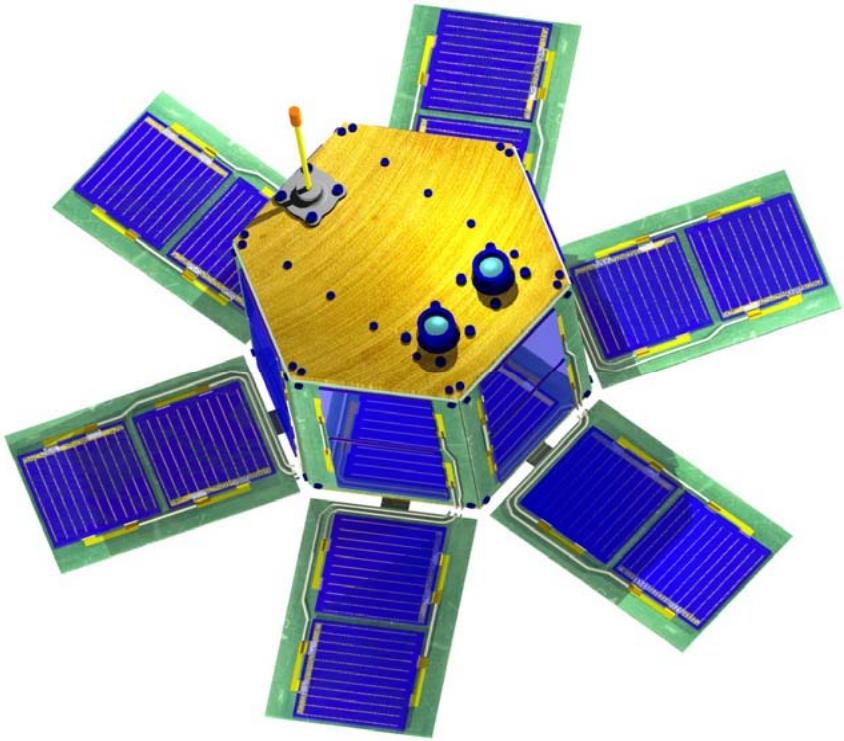


Actual and Prospective Missions

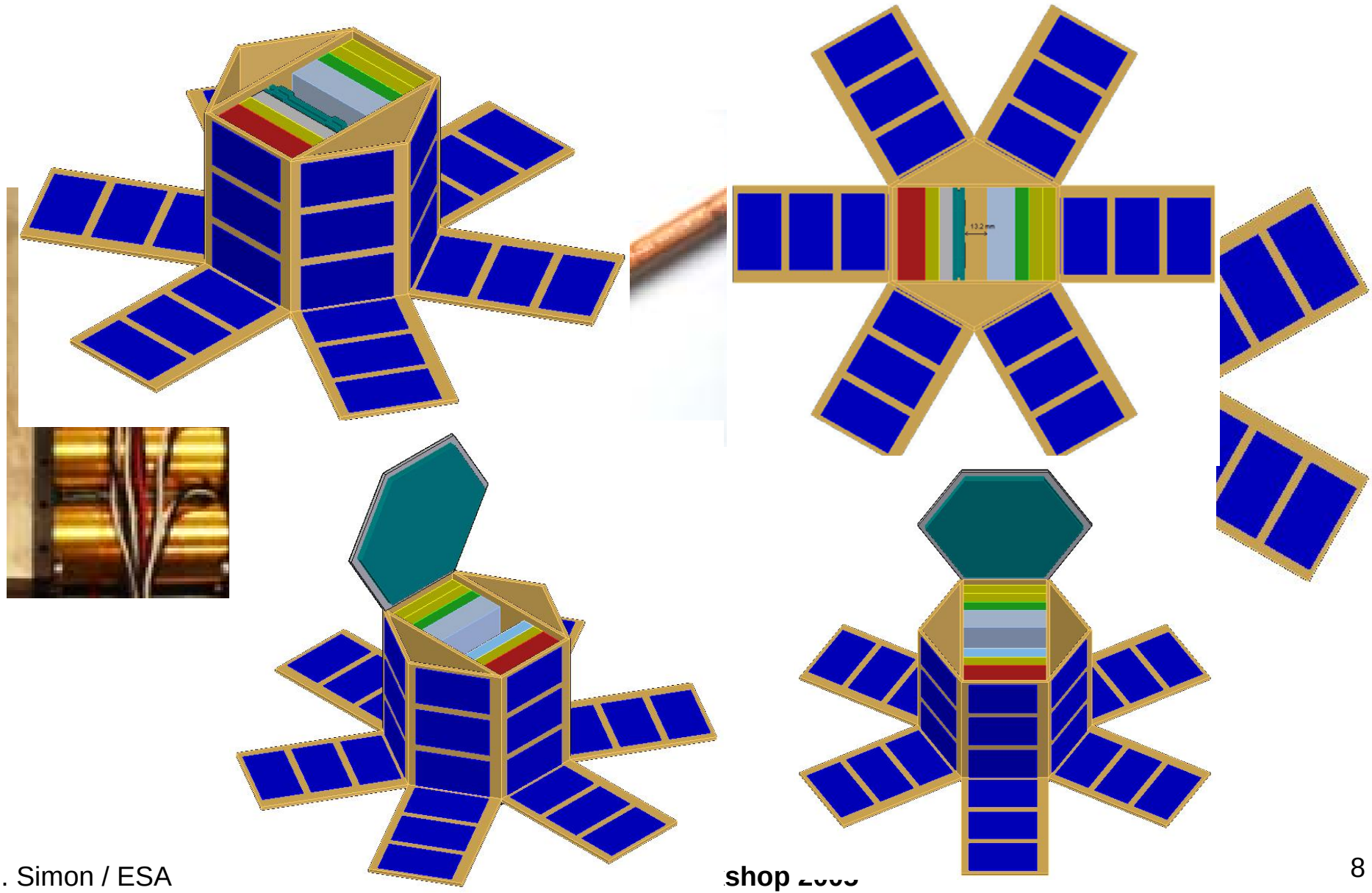
- Rosetta
- Planetary UAV
- Venus Orbiter
- SNAP-1, SNAP-2
- RapidEye
- Palmsat
- MMS
- GSTB-V2/A
- Eurostar3000
- Mars/Lunar Base Stations
- Herschel Plank
- Beagle 2
- Radarsat

Lithium Polymer as a Mission Enabler

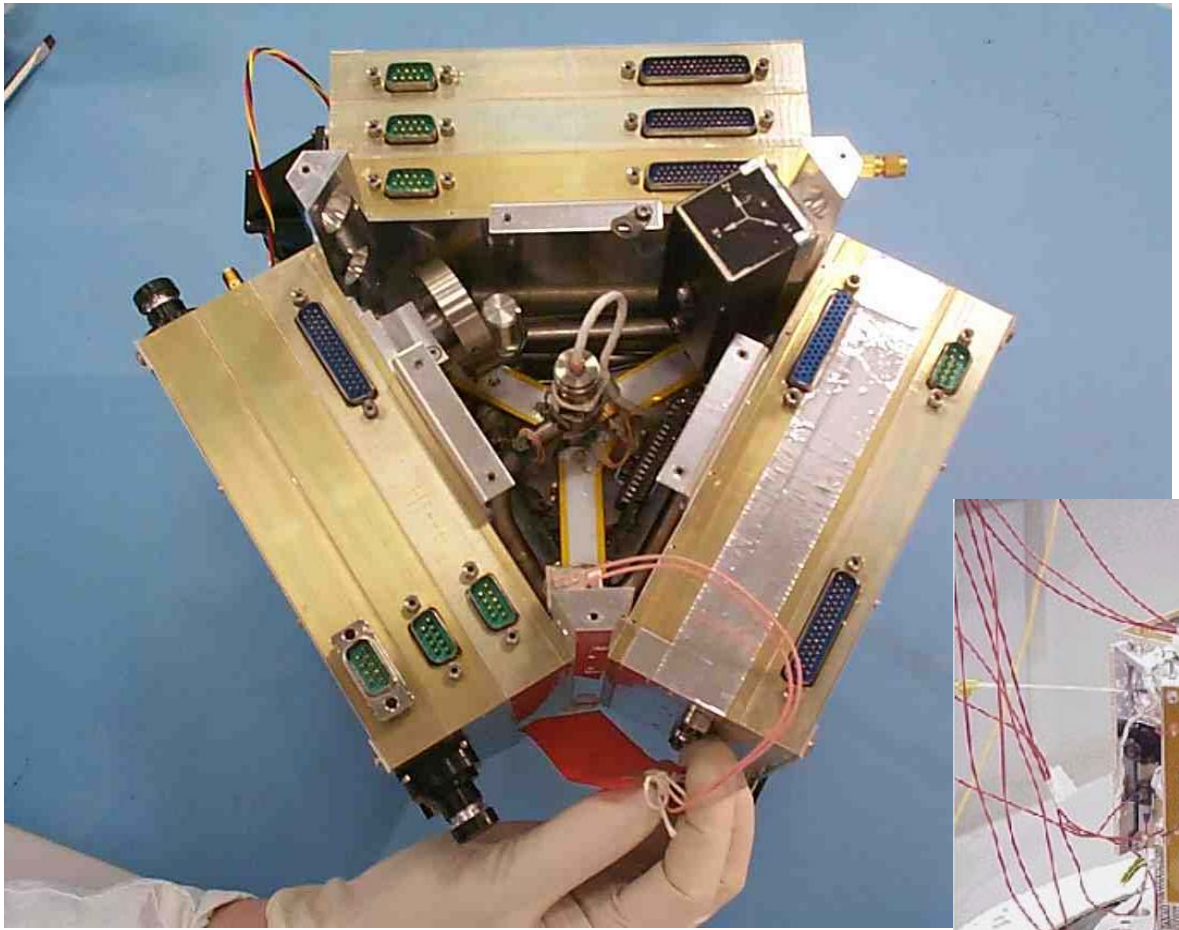
- Miniature Spacecraft
  - Trend towards miniature spacecraft.
  - Flat packed, rectangular nature and high cell voltage of Lithium polymer technology is ideal for the design of miniature spacecraft

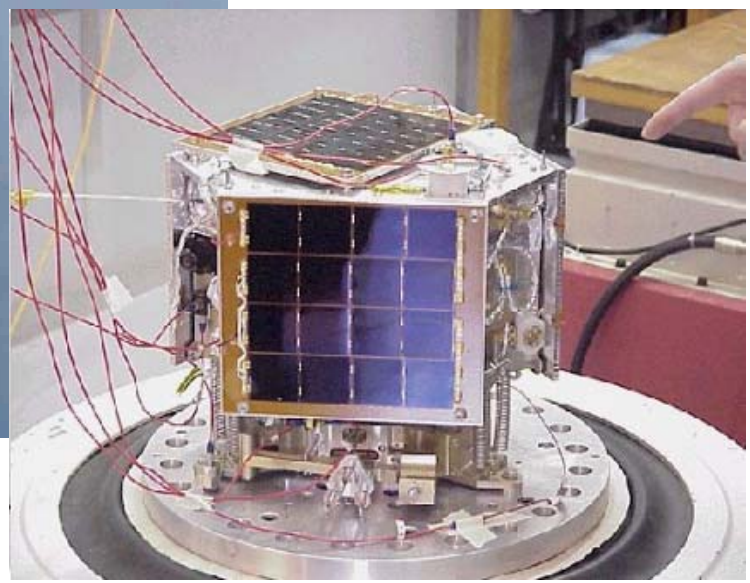


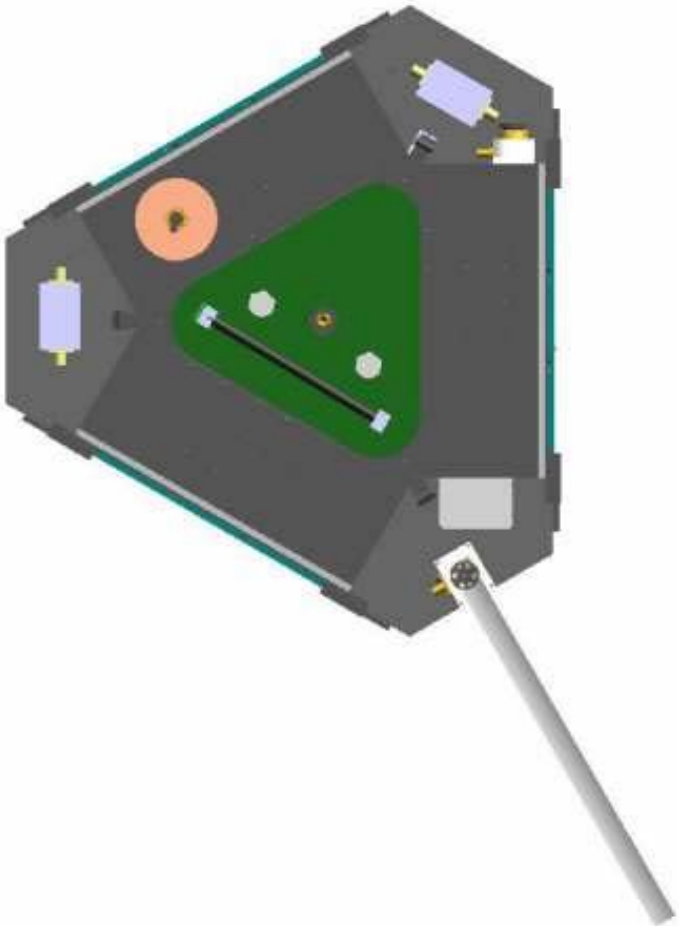
PALMSAT


13.2 mm

SNAP-2

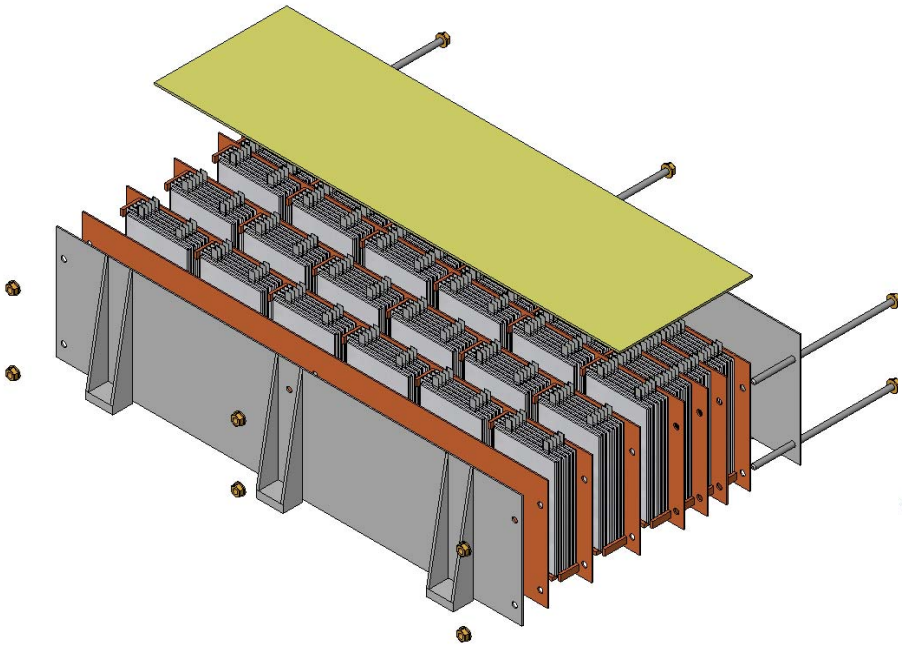




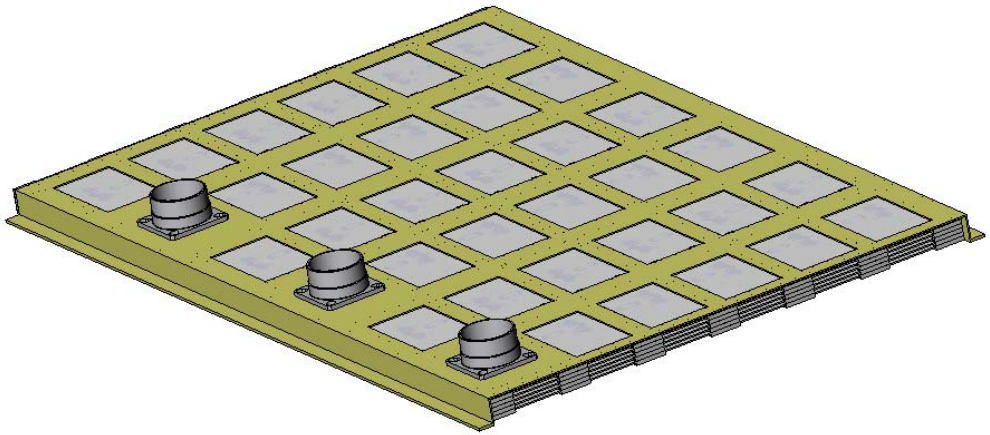


Two conceptual battery designs evaluated (AEAT)

- Concept A: traditional



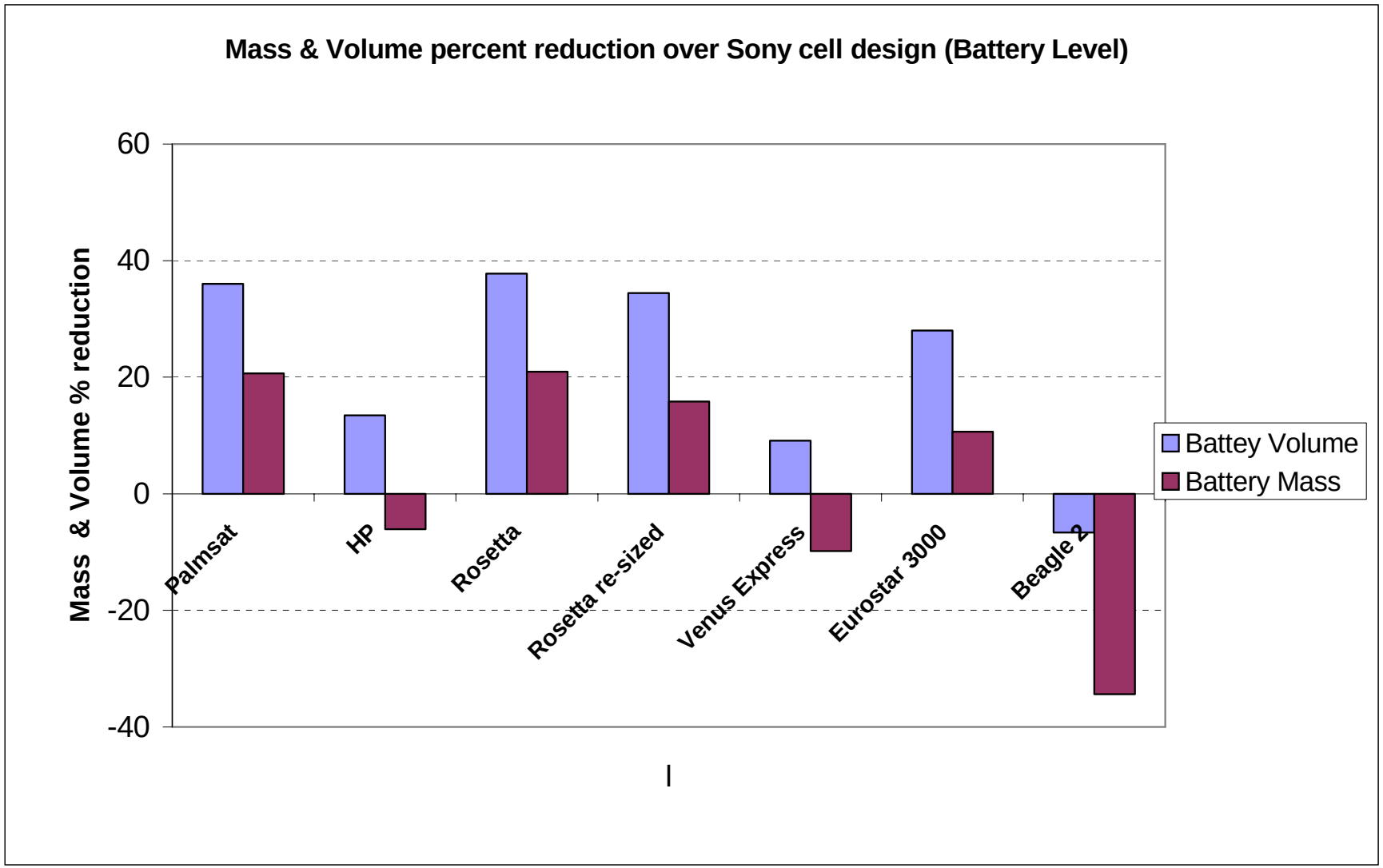
- Concept B: flat panel



- Missions evaluated by comparing
  - 1.6Ah Lithium Polymer cell
  - 1.5Ah Lithium-ion cell

- Mass benefits on Palmsat, Rosetta, Eurostar3000

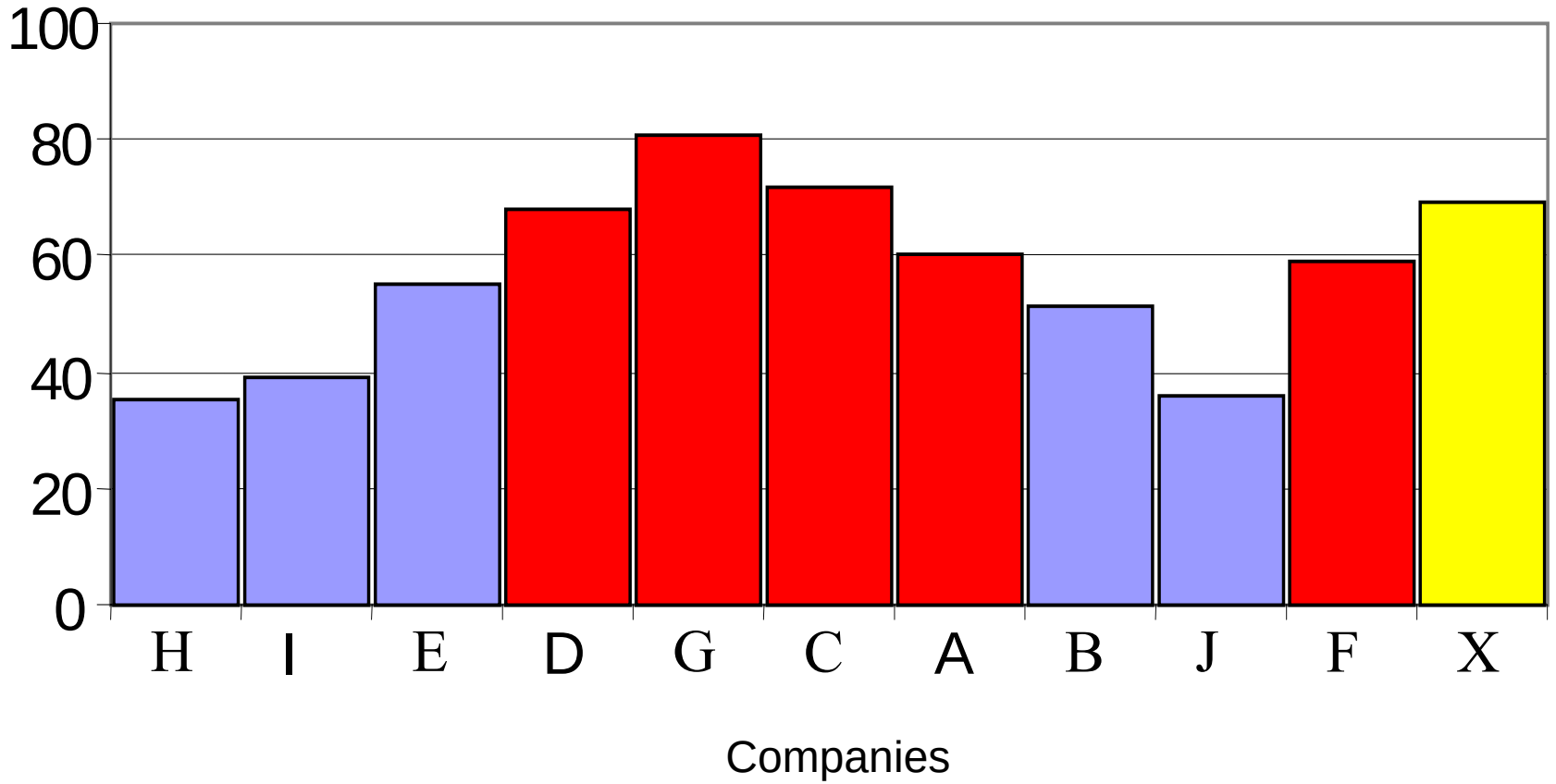
  - However, comparison with contemporary Lithium-ion rather than early 1990's technology
  - Additional Mass benefits possible (Concept B)
  - Heritage limits large platform applications (Eurostar3000)


Mass & Volume percent reduction over Sony cell design (Battery Level)
Mass & Volume % reduction
60
40
20
0
-20
-40
Palmsat
HP
Rosetta
Rosetta re-sized
Venus Express
Eurostar 3000
Beagle 2
Battey Volume
Battery Mass

Selection of Li ion Polymer cells

Evaluation Criteria	Weight	Scoring
Technical		Total of 30 points for technical
Energy Density	10	
Cycle Life	5	
Radiation Tolerance	10	
Outgassing	5	
Survey Responsiveness	15	Willingness to participate in space applications
Commercial	20	Geopolitical factors, economic stability
Flexibility	10	Capability to manufacture different chemistry and size variants
Manufacturing Volume	10	Favours small production volumes over prototyping/high vol.
Space Herirage	15	Cell heritage

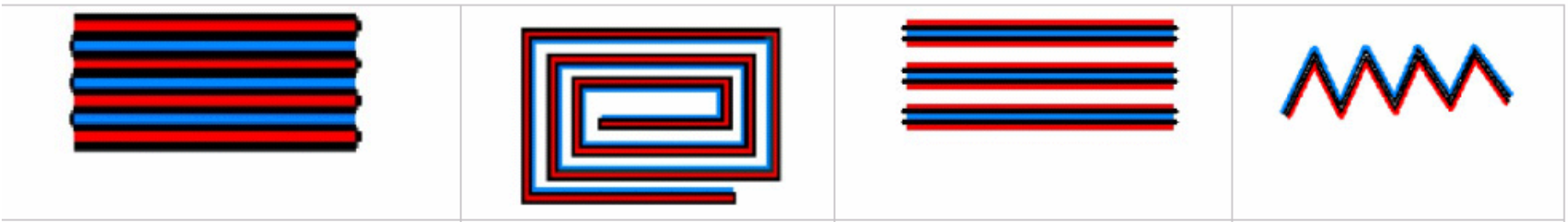
Total Scoring



Evaluation Testing

Capacity @ C/10 under vacuum:

- Only F is not affected
- Capacity recovered under atmospheric pressure



A and C	D	F	G

^{60}Co radiation test up to 500 Krad: No effect noticed

- **Test**
- Vacuum
- DPA
- Radiation
- **Capacity**
- **Resistance**
- **Self discharge**
- Mission scenario
- EMF vs SOC

Test	24hr storage	-10ºC	0ºC	20ºC	40ºC
A	✓	✓	✓	✓✓	✓✓
C	✓	✓	✓✓	✓✓	✓✓
D	✓	✓	✓	✓✓	✓✓
F	✓	✓	✓✓	✓✓	✓✓
G	x	x	✓	✓✓	✓✓

Capacity @ C/10

- **Test**
- Vacuum
- DPA
- Radiation
- Capacity
- Resistance
- Self discharge
- **Mission scenario**
- EMF vs SOC

Test	LEO 20ºC	GEO 20ºC	Lander 0ºC	Lander 20ºC	Lander 40ºC
A	✓	✓	✓	✓	✓
C	✓	✓	✓	✓	✓
D	✓	✓	✓	✓	✓
F	✓	✓	✓	✓	✓
G	✗	✗	✗	✓	✓

LEO Discharge: C/4 / Charge: C/2 (5 cycles)

GEO Discharge: C/2 / Charge: C/10 (5 cycles)

Lander Discharge: C/15 / Charge: C/10 (5 cycles)

Test	A	C	D	F	G
Vacuum	✗	✗	✗	✓	✗
DPA	✓	✓	✓	✓	✓
Radiation	✓	✓	✓	✓	✓
Capacity	✓	✓✓	✓	✓✓	✗
Resistance	✓	✓✓	✓	✓✓	✗
Self discharge	✓	✓	✓	✓	✗
Mission scenario	✓	✓	✓	✓	✗
EMF vs SOC	✓	✓	✓	✓	✓

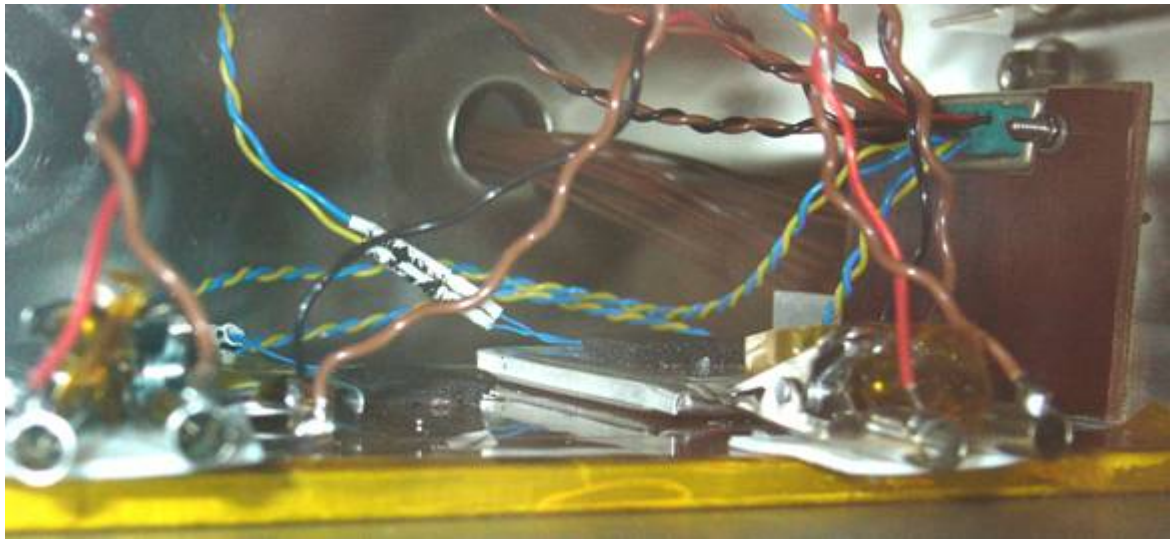
Cycling Tests (ESTEC)

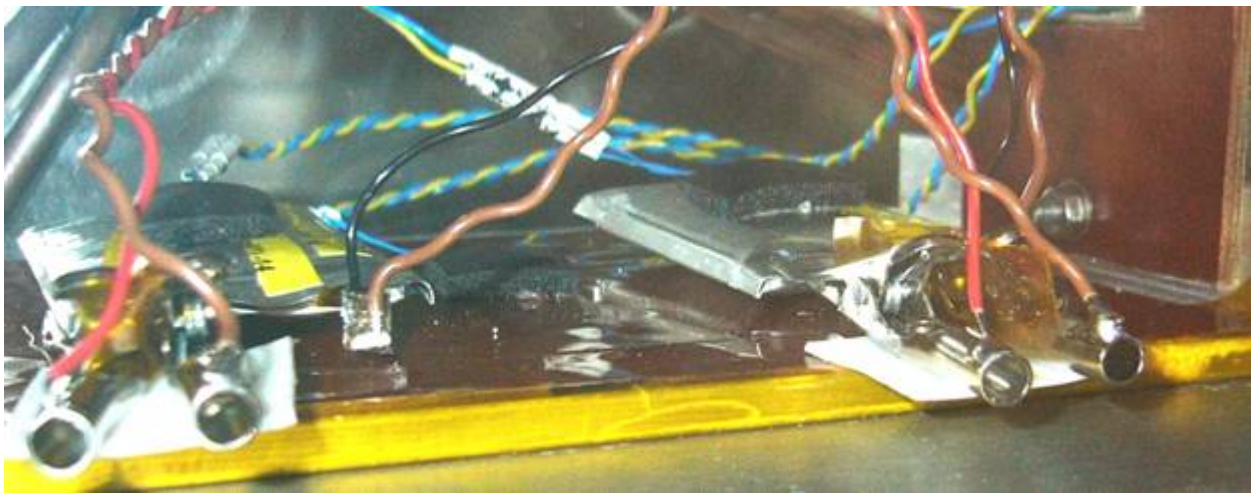
- Under atmospheric pressure

- Under reduced pressure (15-20 mbars)

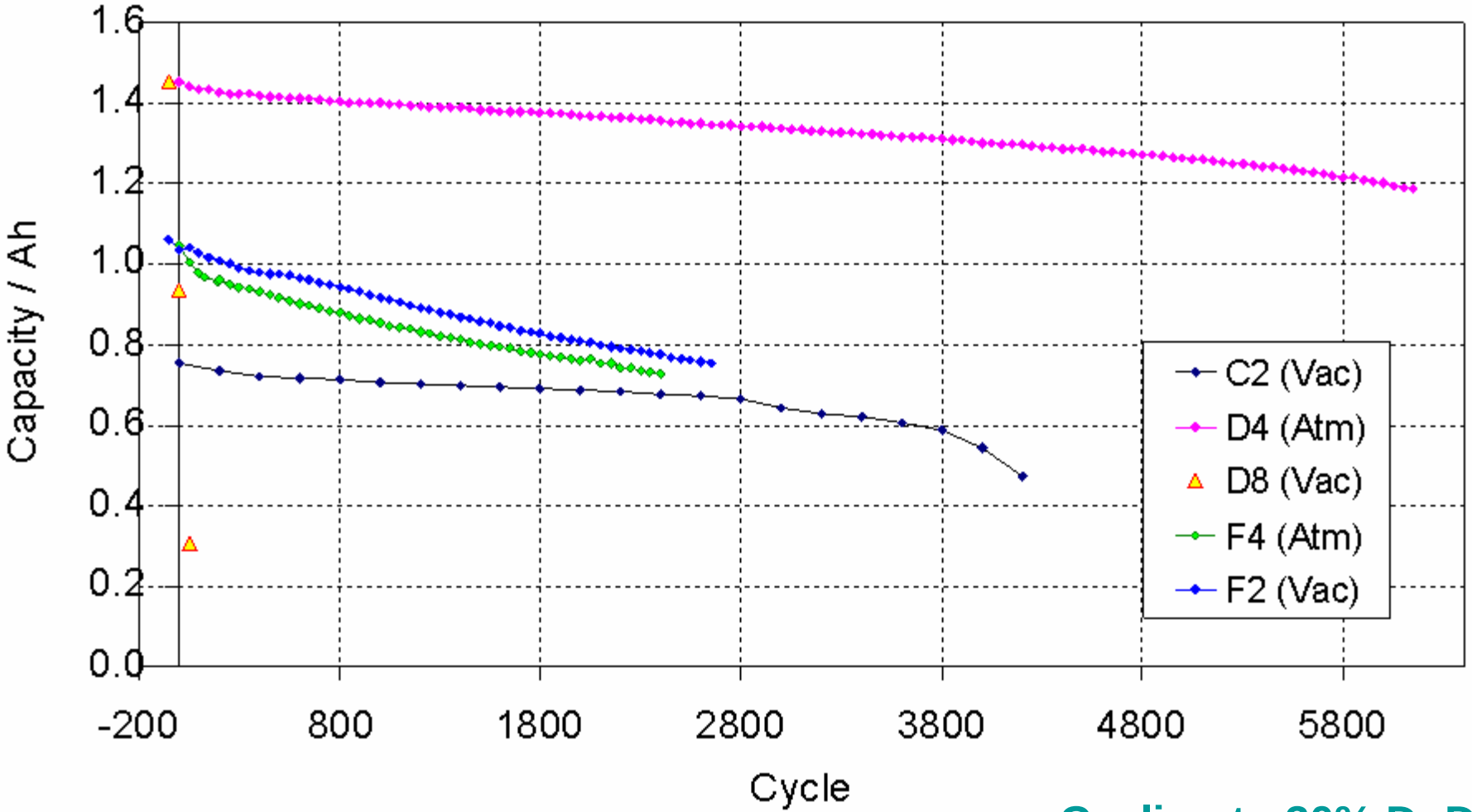
30 % or 80 %DoD cycling at 20°C, capacity check every 50 cycles.
Discharge rate: C
Charge rate: C/2 + tapering

Manufacturer C	Nominal capacity =	0.80 Ah
Manufacturer D	Nominal capacity =	1.45 Ah
Manufacturer F	Nominal capacity =	1.05 Ah

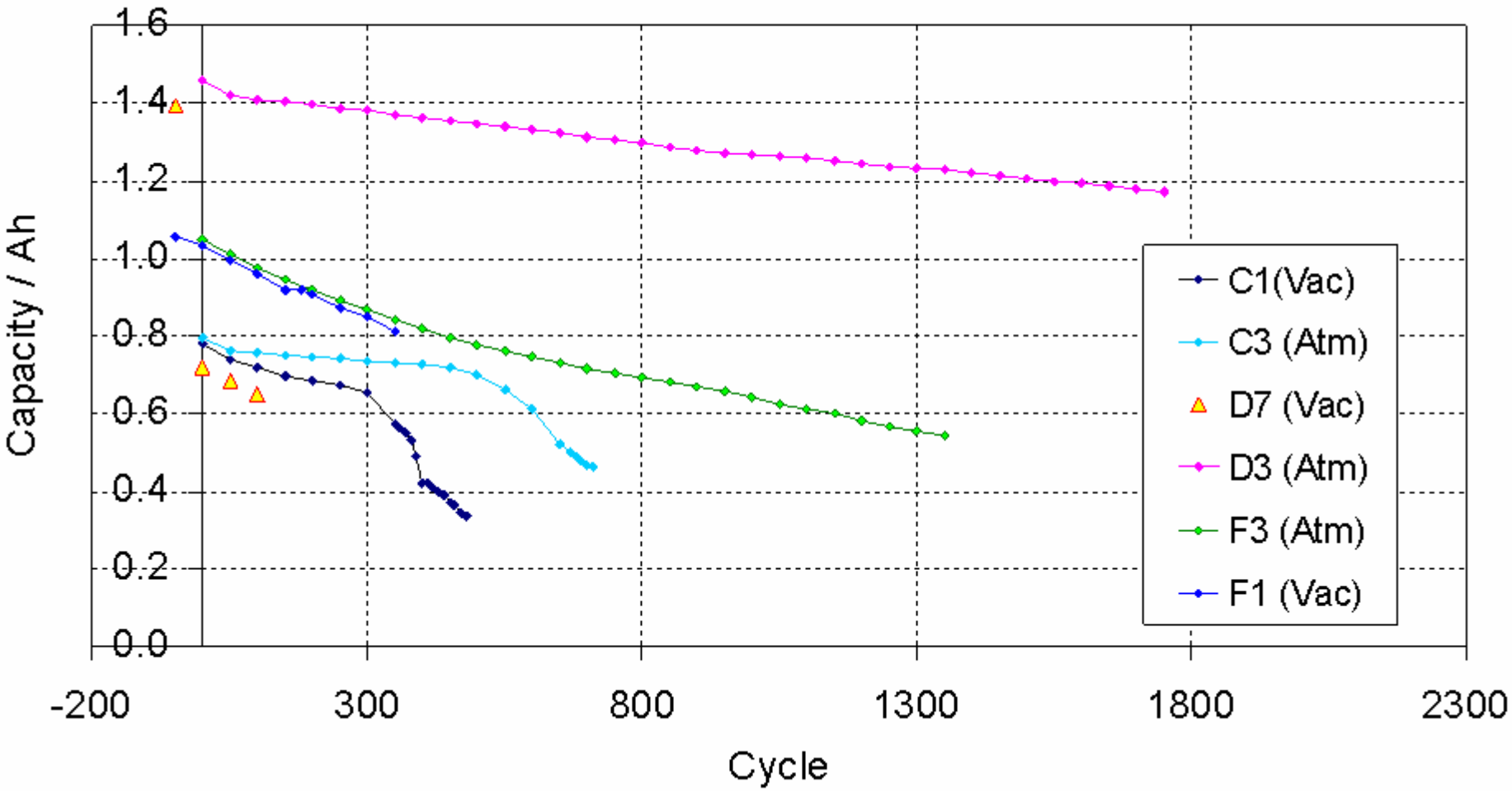




Capacity Check



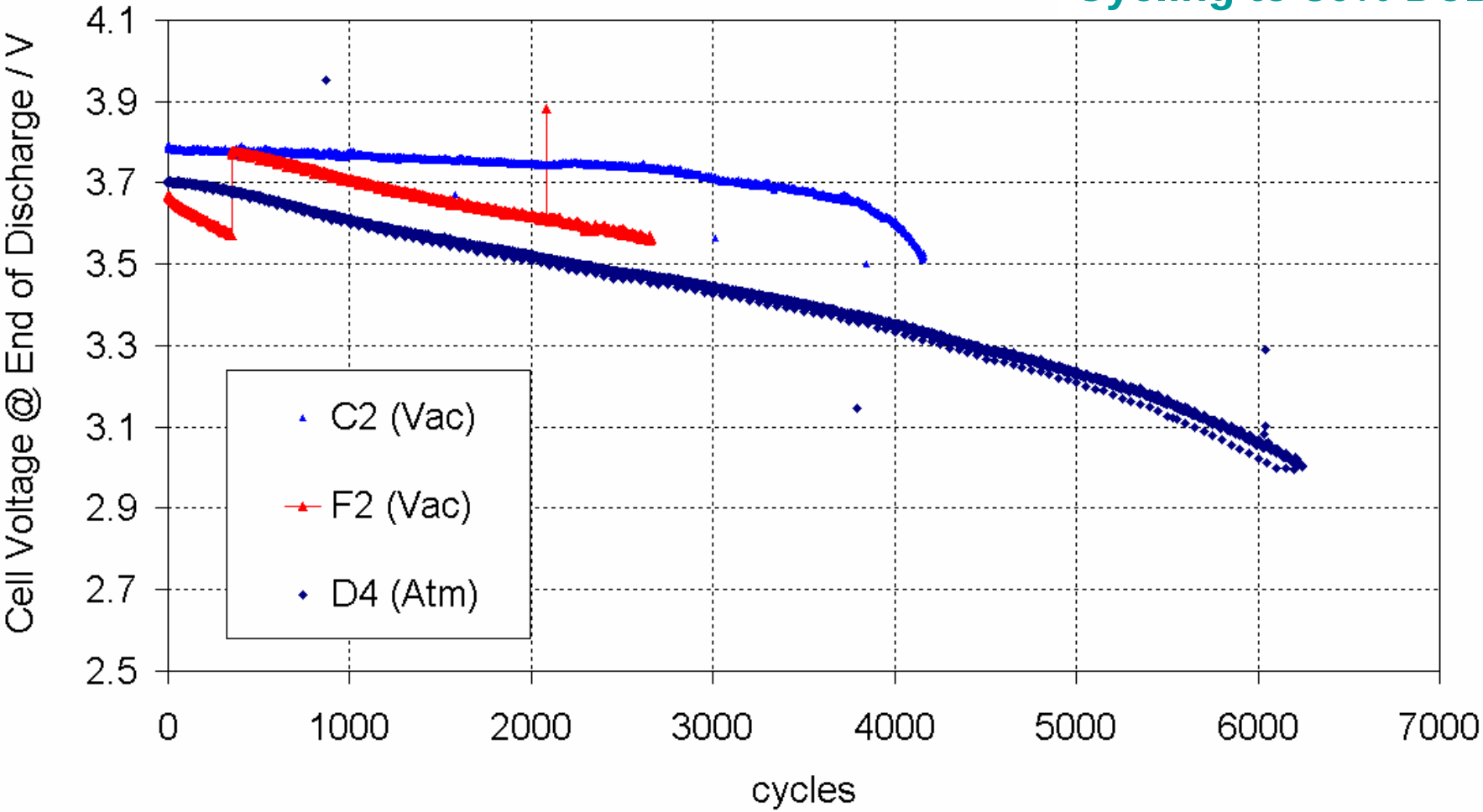
Cycling to 30% DoD



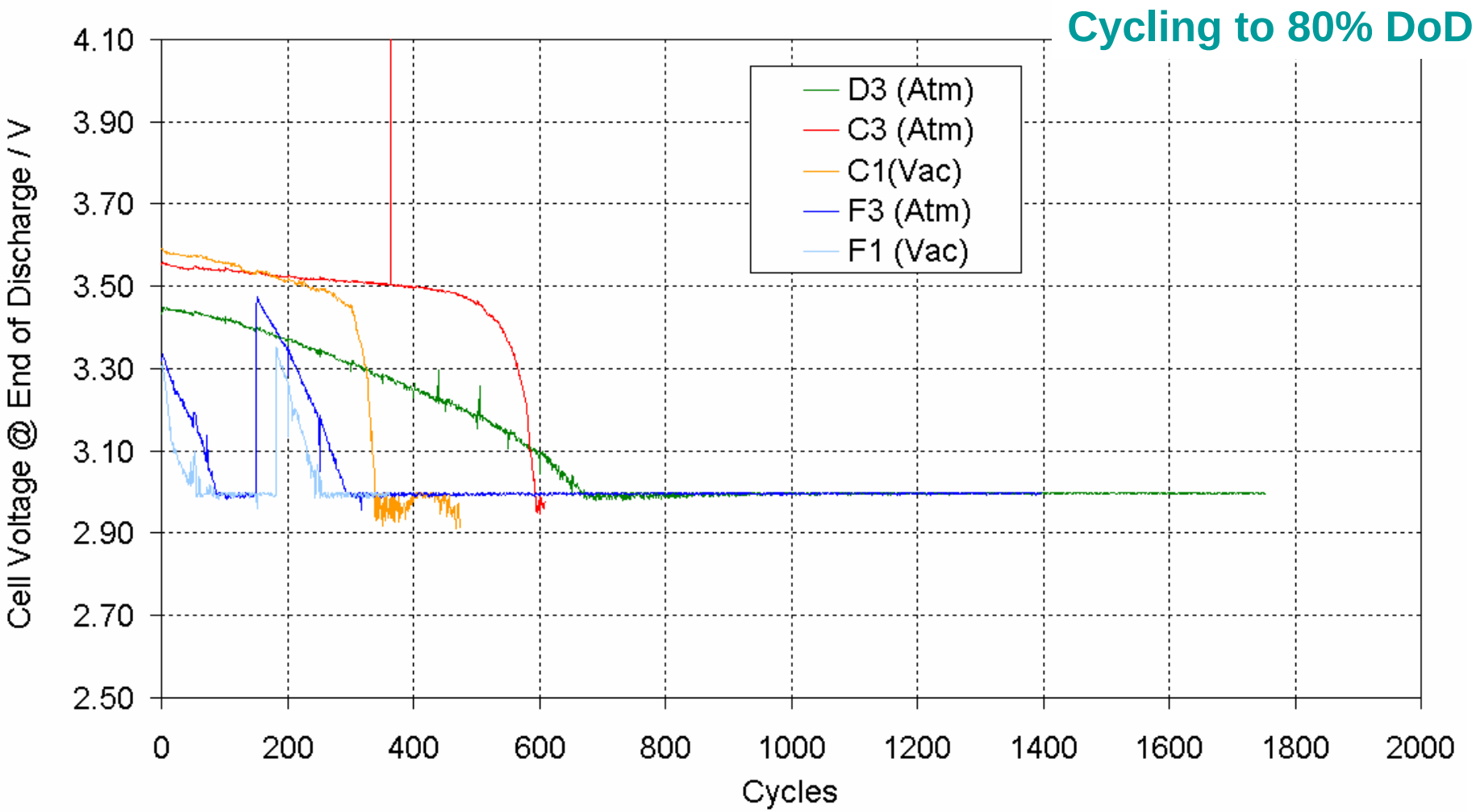
Cycling to 80% DoD

End Of Discharge Voltage

Cycling to 30% DoD

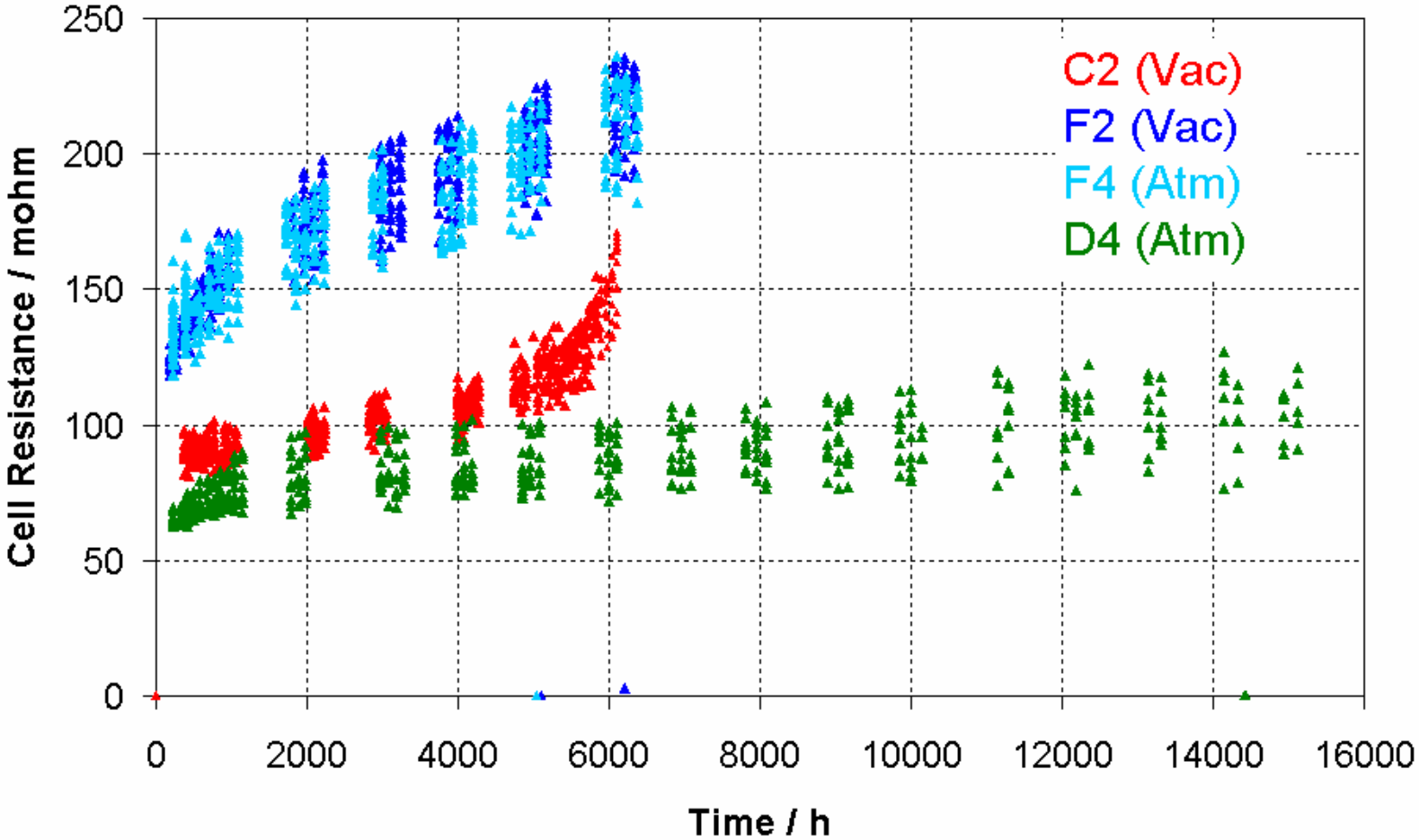


End Of Discharge Voltage



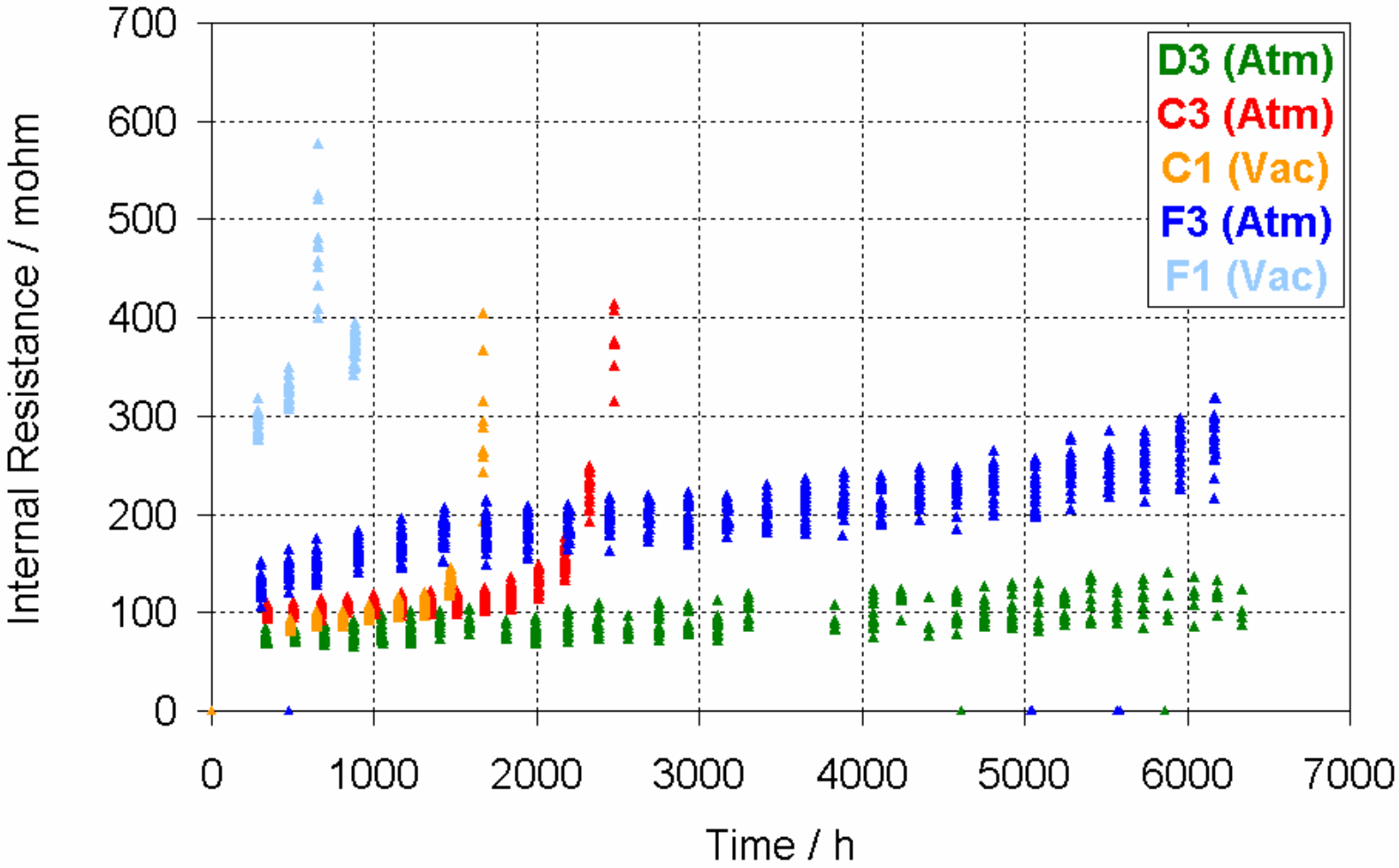
Internal Resistance

Cycling to 30% DoD



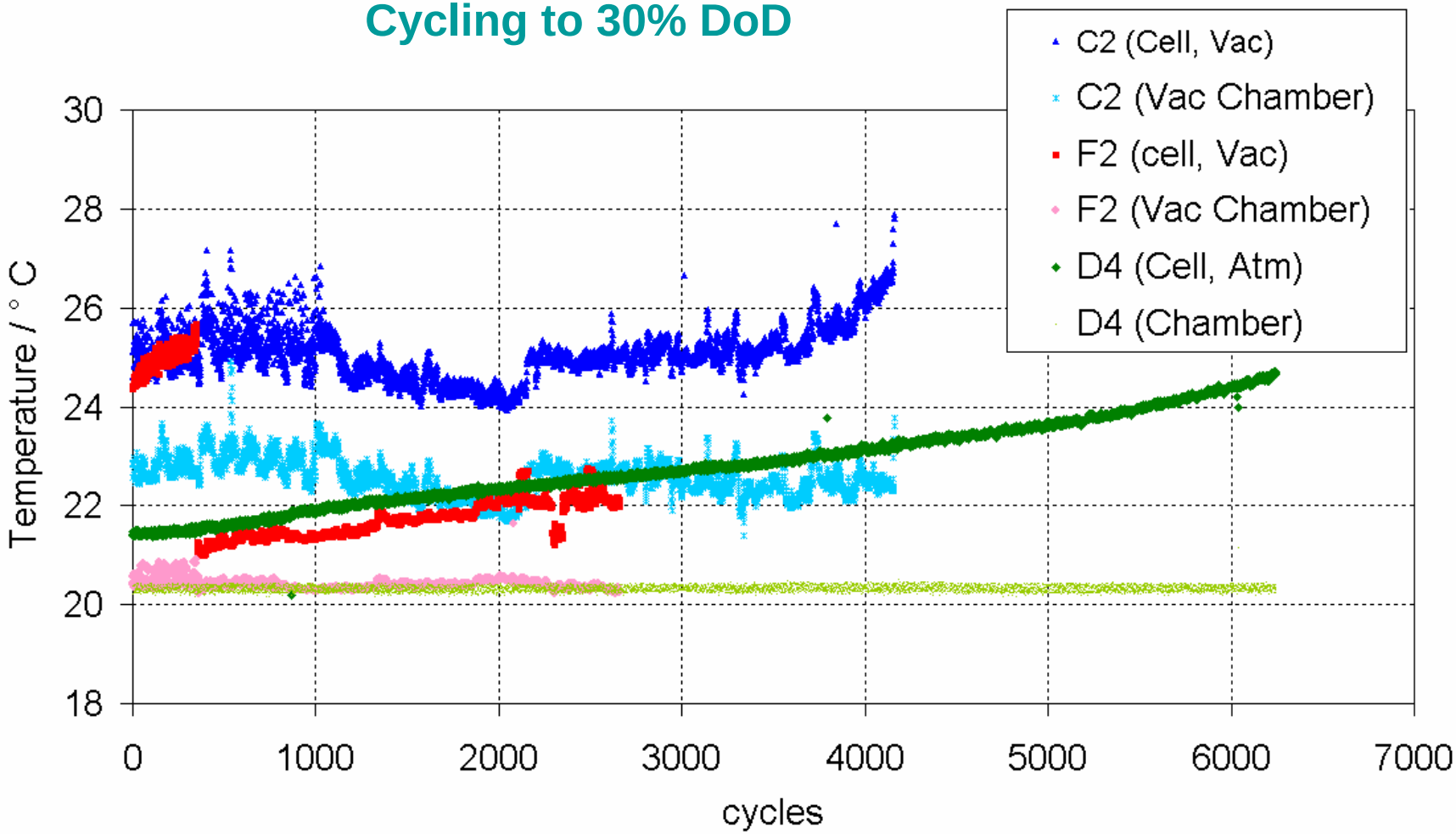
Internal Resistance

Cycling to 80% DoD



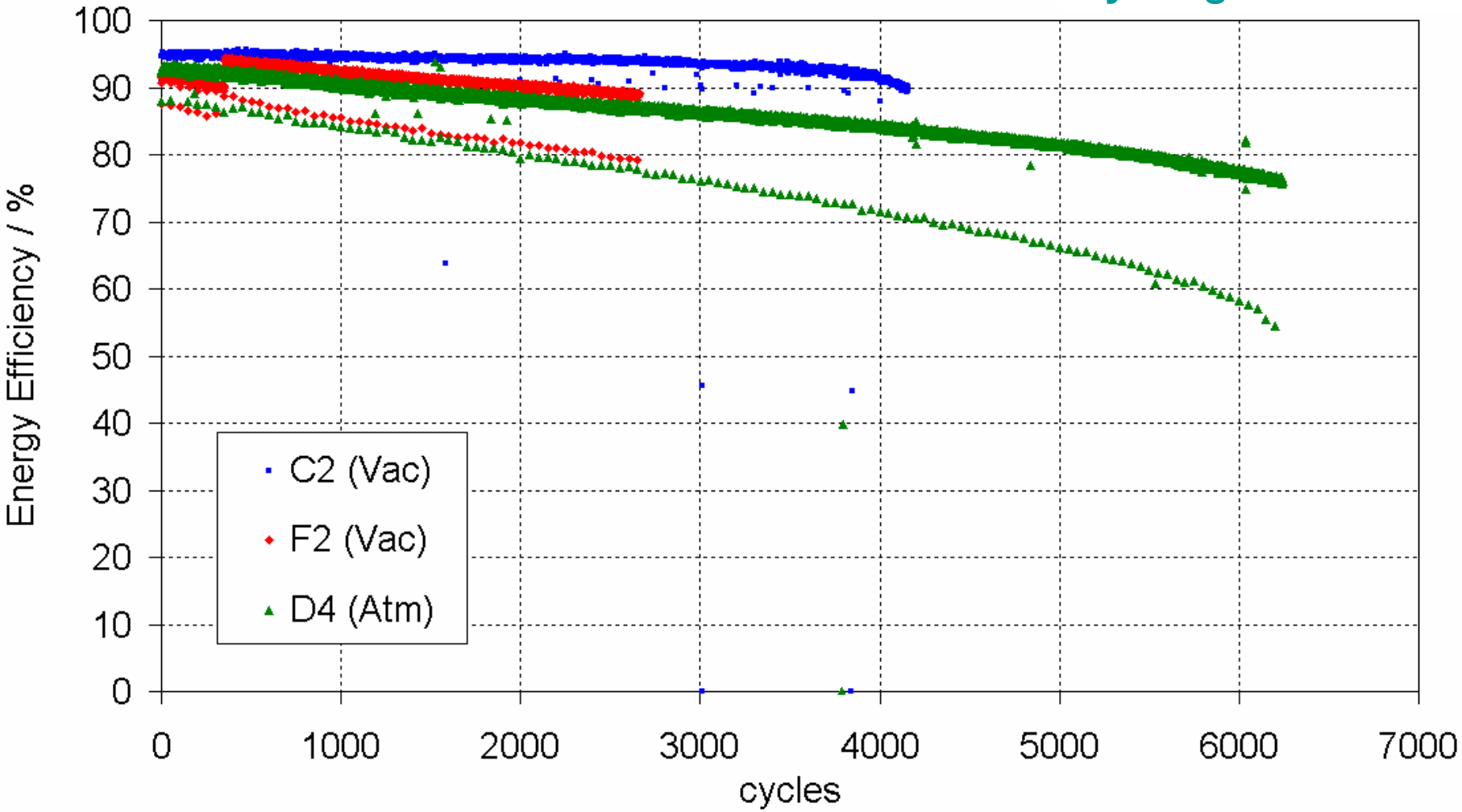
EOD Temperature evolution

Cycling to 30% DoD



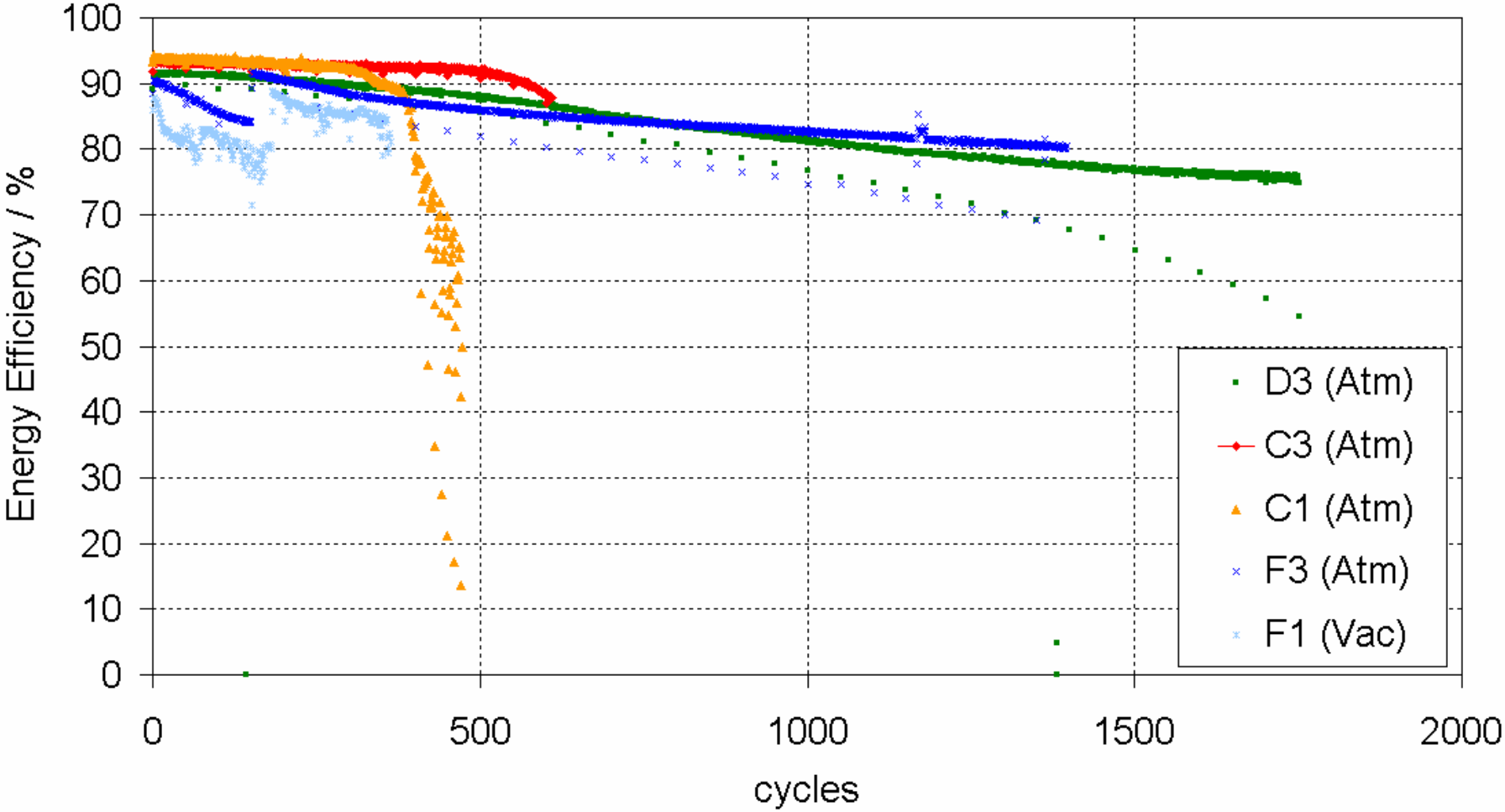
Energy Efficiency

Cycling to 30% DoD



Energy Efficiency

Cycling to 80% DoD



Conclusions

- Geometric Flexibility of most interest for spacecraft inherently volume limited
- Battery packaging offers for lower mass battery and multiple options for location within the spacecraft structure
  Can take advantage of unutilised volume within the spacecraft.
- 5 lithium polymer batteries evaluated : “Lithium-ion-in-a-bag” rather than true polymer
- Not sensitive to γ-radiation (up to 500 Krad) but need further testing
- Some batteries tested sensitive to vacuum environment (15-20 mbar)
- Cycle life under vacuum:
  - 30 % DoD : > 4000 cycles for C, 1500 cycles for F (C/3 discharge) [still on-going for F]
  - 80 % DoD : 400 cycles for C, 350 cycles for F (C/3 discharge)

Acknowledgements

- European Space Battery Test Centre (ESBTC)
- SSTL
- AEAT (now ABSL Space Products)