

# Development of the lithium-ion cells for lunar exploration programs

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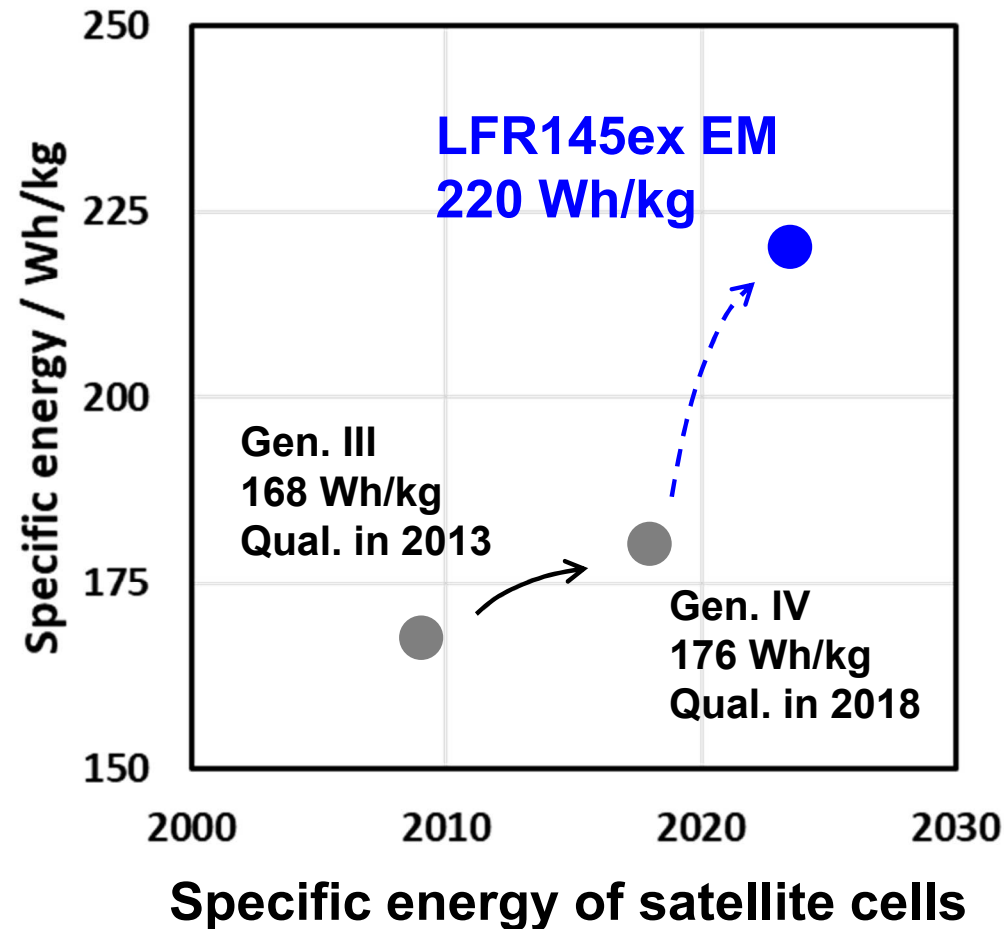
# Background

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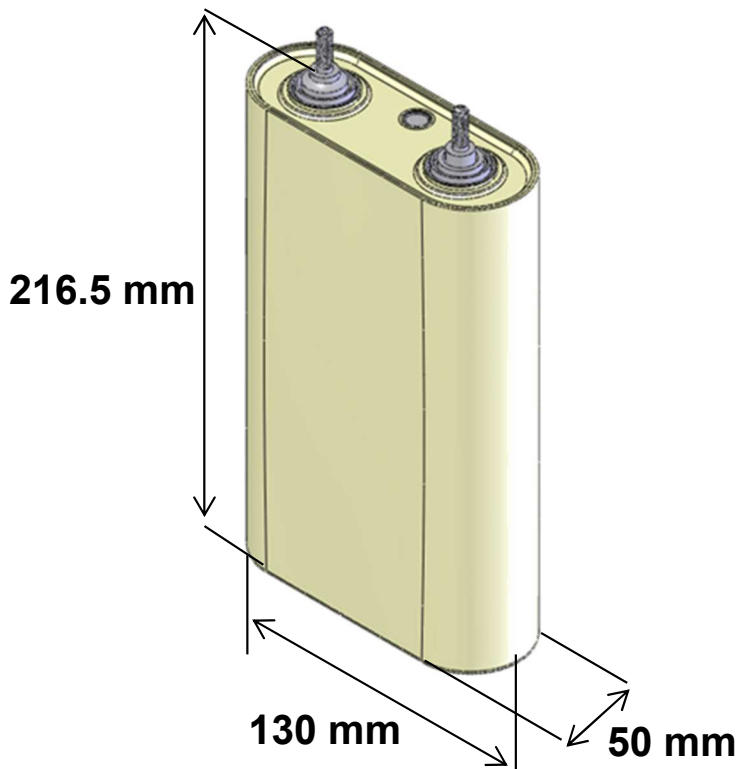
- ✓ **GYT developed the generation II, III and IV cells for satellite in cooperation with JAXA.**
  - **Gen. II : Qualified in 2008**
  - **Gen. III : Qualified in 2013**
  - **Gen. IV : Qualified in 2018**
- ✓ **The development of the lithium-ion cells for lunar exploration programs was also commissioned to GYT because these developments and superior flight performance to date have been highly evaluated by JAXA.**

# Design concept

- ✓ Increase the specific energy to 220 Wh/kg
- ✓ Superior cycle life performance at least up to 200 cycles to allow multiple overnights on the Moon
- ✓ Use the reliable heritage structure so that battery assemblers don't have to change their basic battery designs



# Target cell specification

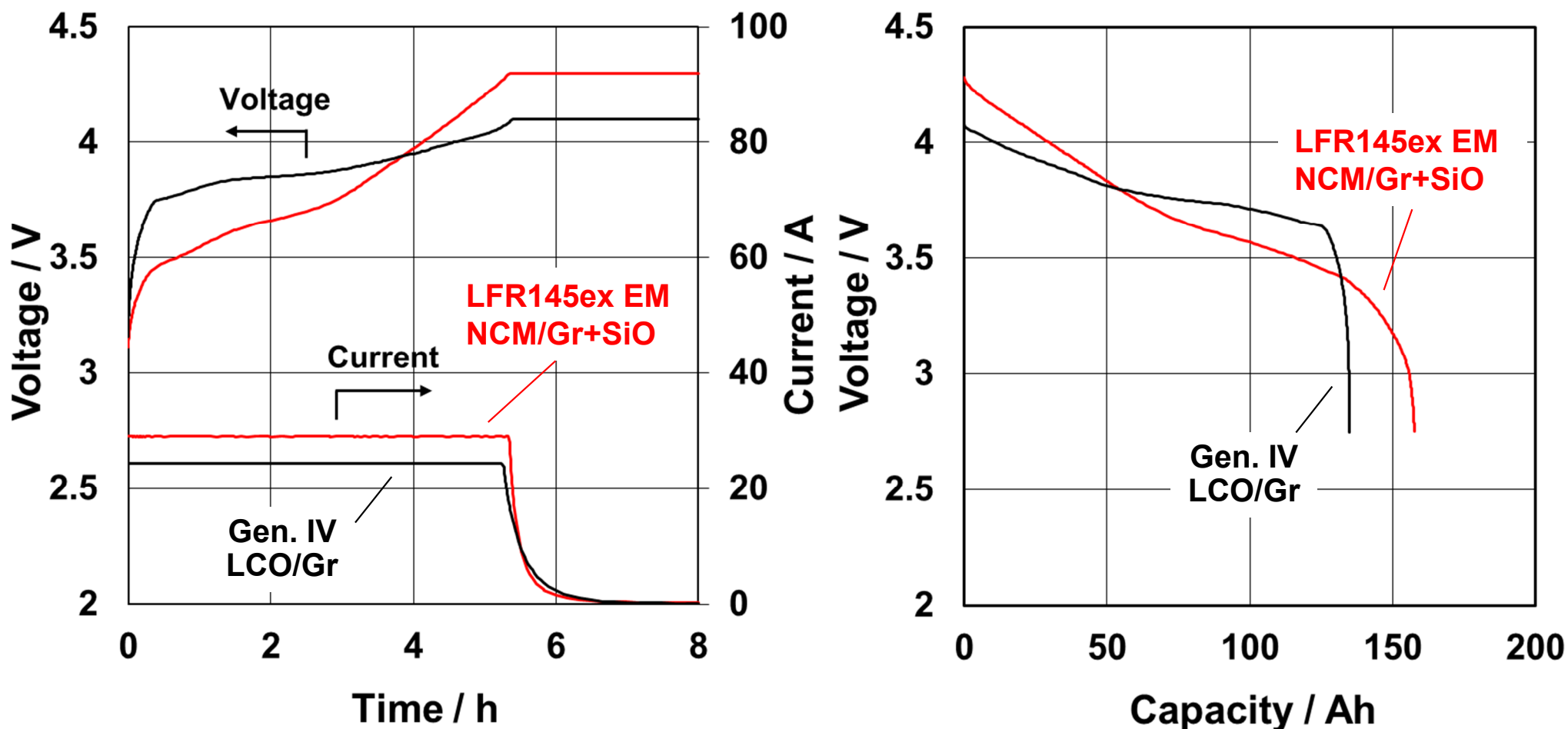


Appearance of LFR145ex EM cell  
(Same size as 120 Ah cell)

Cell	LFR145ex EM	Generation IV (120 Ah)
Chemistry	<b>NCM/Gr+SiO</b>	LCO/Gr
Rated capacity / Ah	145	120
Actual capacity / Ah	160*	134
EoCV/ V	4.30	4.10
Discharge Voltage / V	3.69*	3.72
Mass / kg	2.69	2.83
Specific energy / Wh/kg	<b>220*</b>	165

\*Discharge condition: 0.2 CA at 25°C

# Charge and discharge characteristics

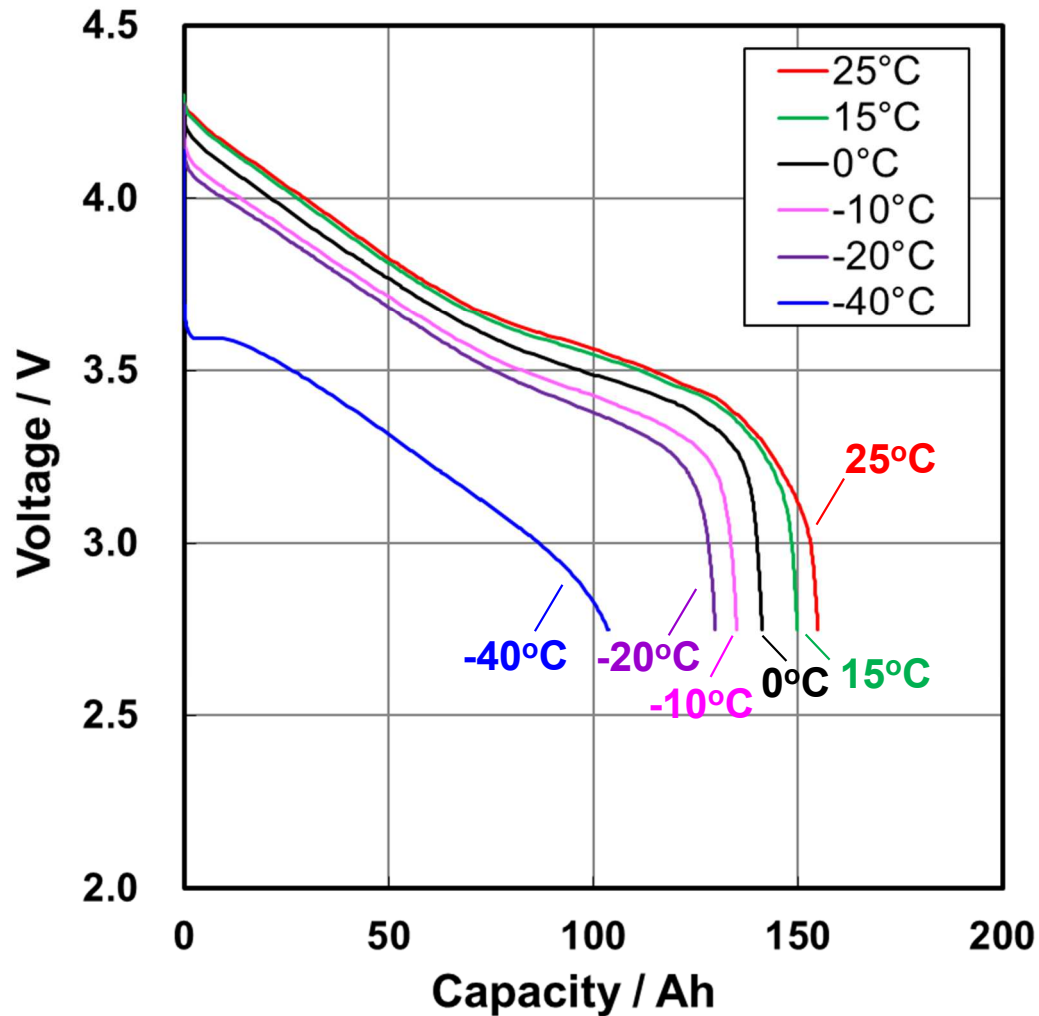


(a) Charge

(b) Discharge

Representative charge and discharge performance of LFR145ex EM cell

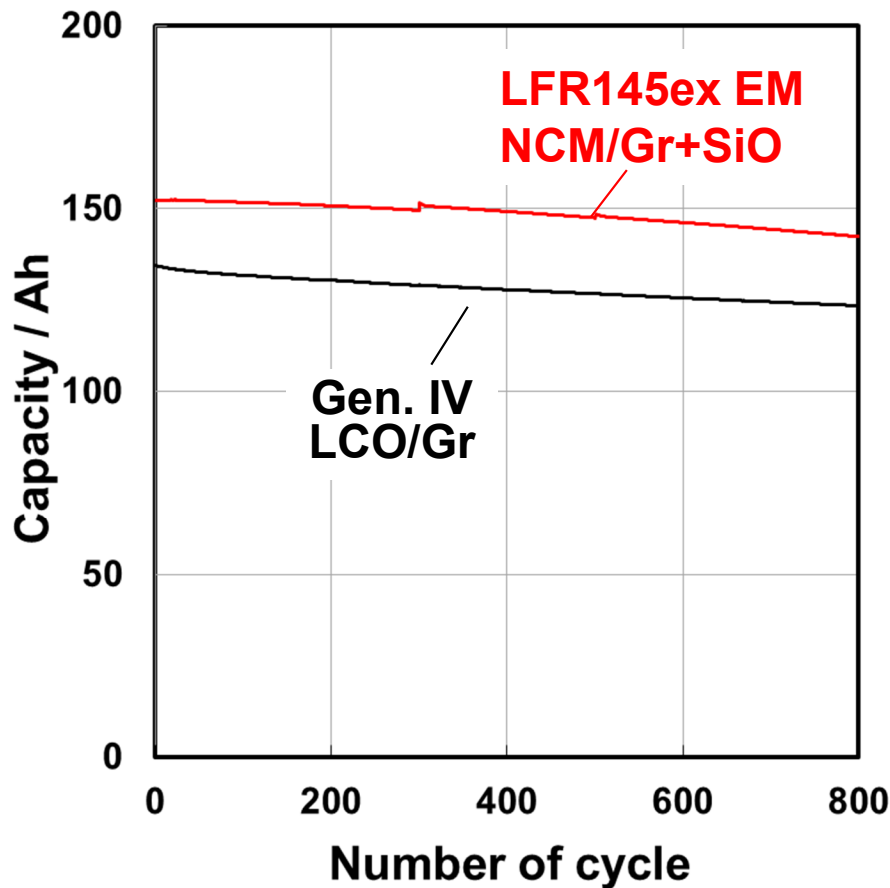
# Effect of temperature



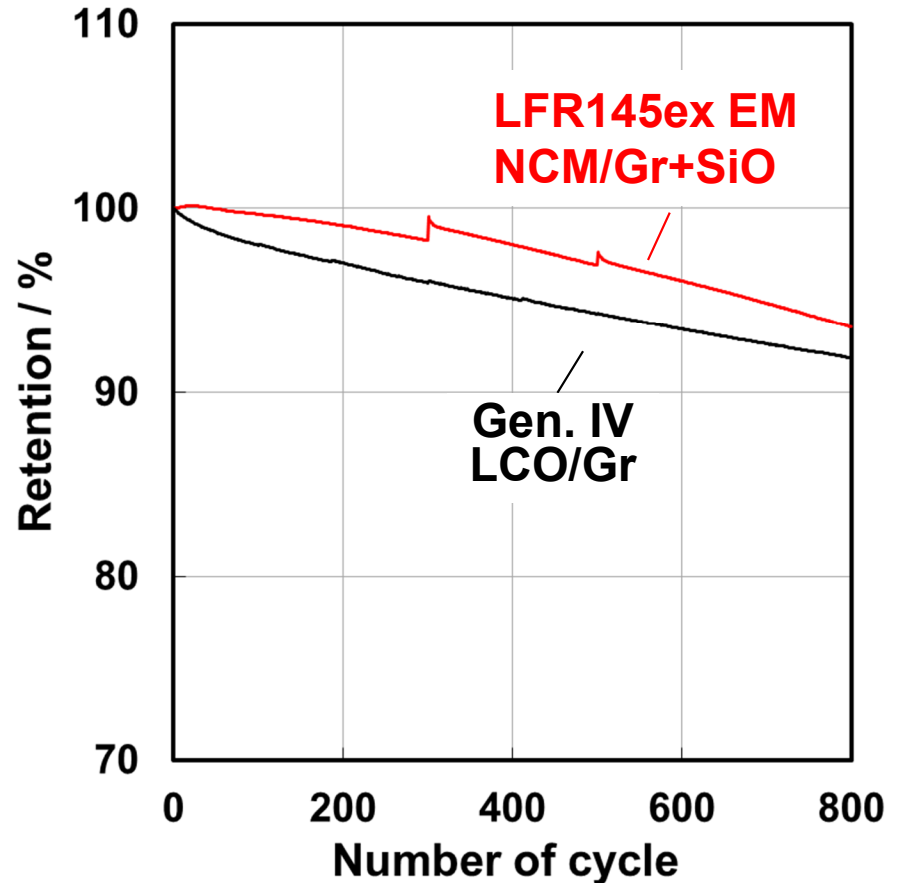
Discharge performance of LFR145ex EM cell at various temperatures

- ✓ The cells demonstrated that it was able to discharge at extremely low temperature.

# Cycle life performance



(a) Capacity

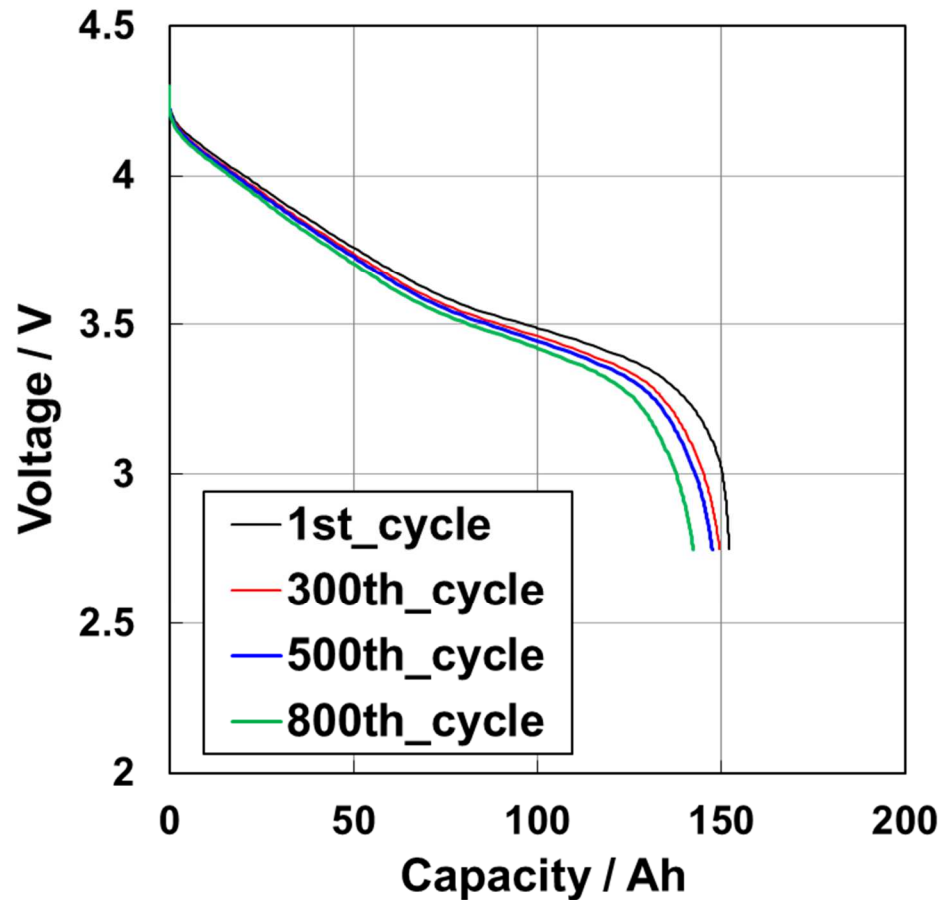


(b) Capacity retention

## Cycle life performance of LFR145ex EM cells

- ✓ The cells demonstrated an excellent life performance to 800 cycles.
- ✓ This superior performance will enable the long-duration exploration on the Moon.

# Cycle life performance

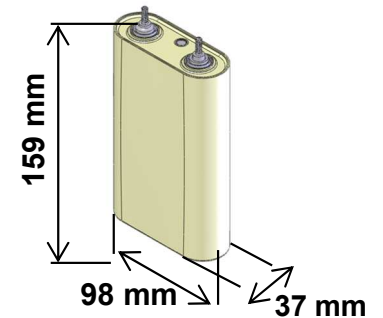


**Changes in discharge performance of LFR145ex EM cells during 100% DOD cycle life test**



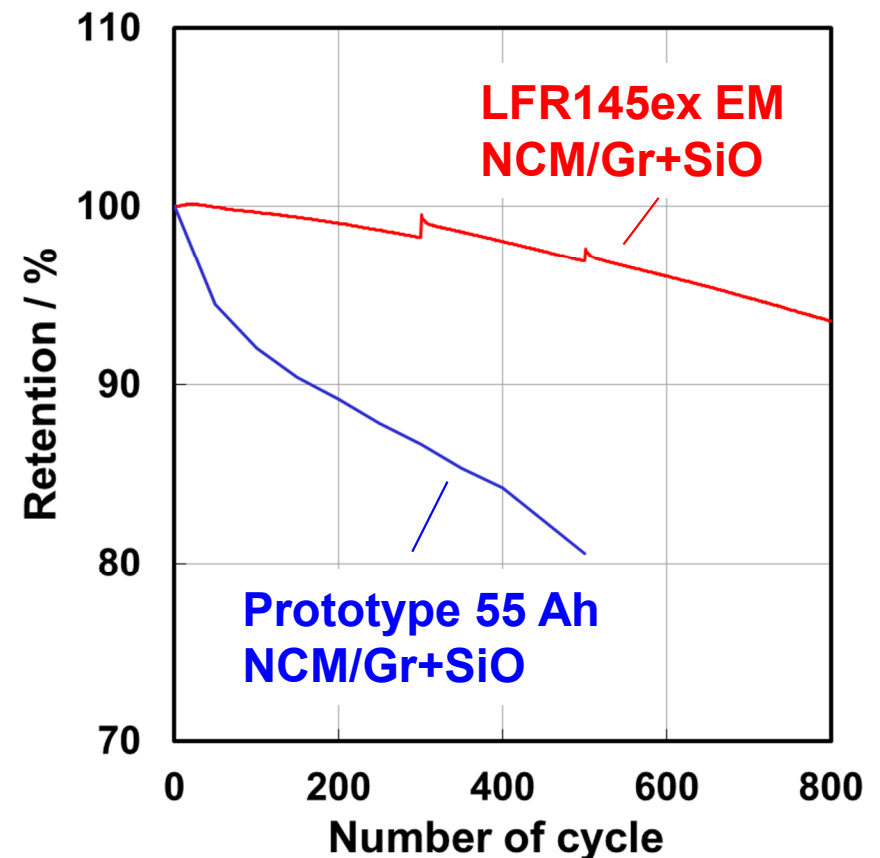
# Operational simulation test (Reference)

- ✓ Prototype 55 Ah cell has been subjected to the operational simulation test.



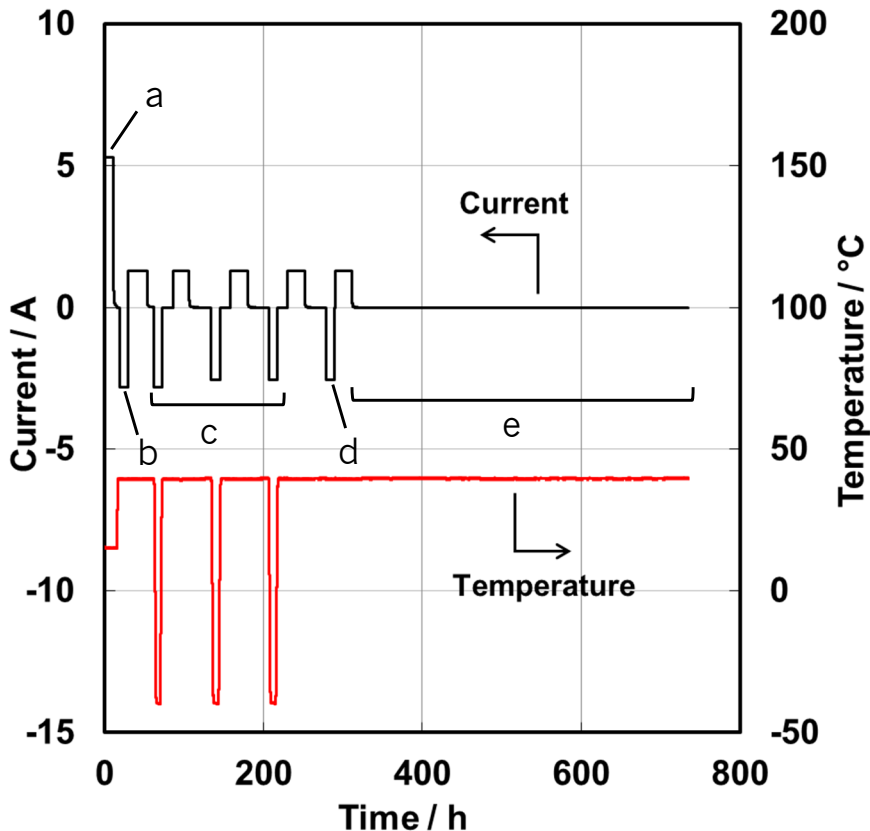
Appearance of prototype 55 Ah cell

Cell	Prototype 55 Ah
Chemistry	NCM/Gr+SiO
Rated capacity / Ah	55
Actual capacity / Ah	60
EoCV / V	4.30
Discharge Voltage / V	3.69
Mass / kg	1.08
Specific energy / Wh/kg	208



Cycle life performance of prototype 55 Ah cell

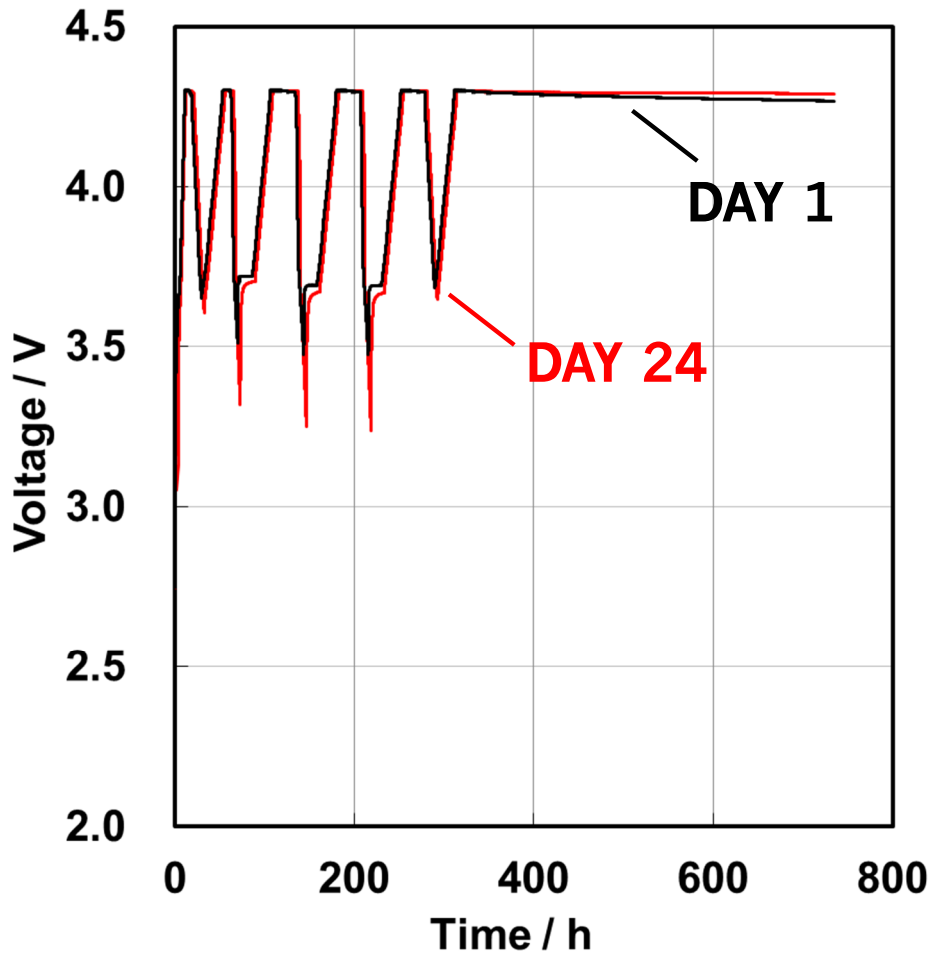
# Operational simulation test (Reference)



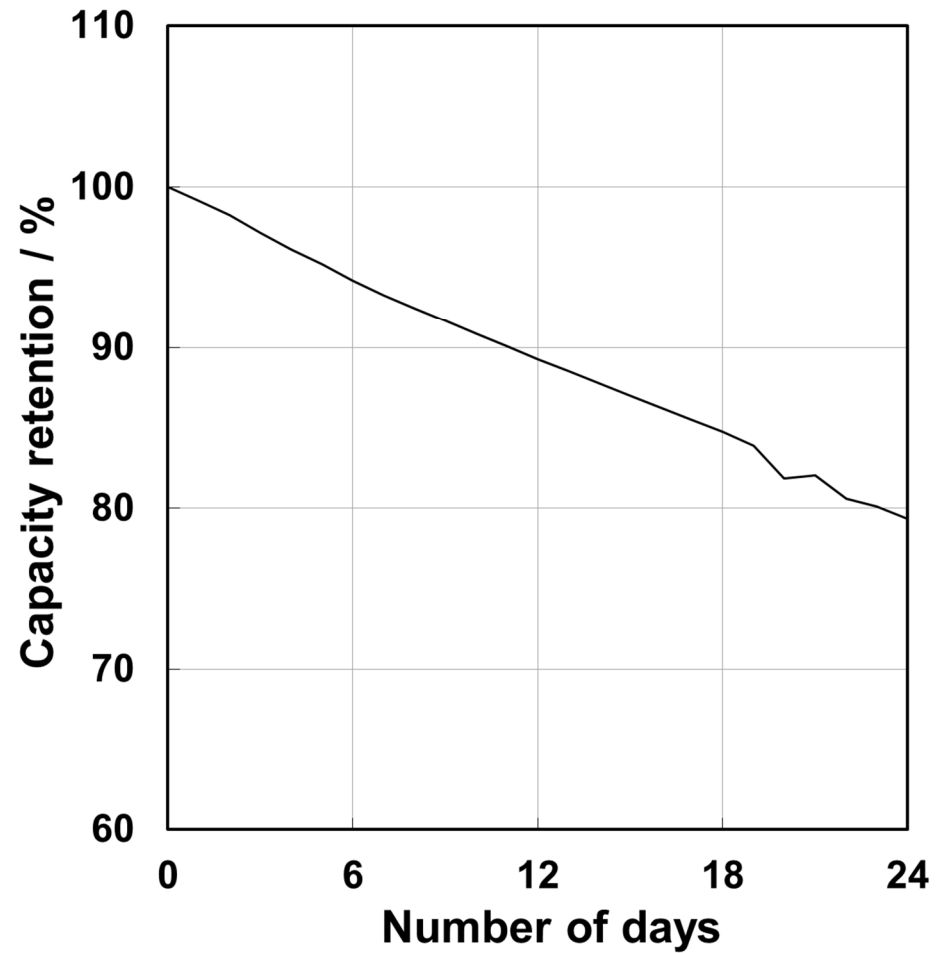
No.	Step	Temperature	Maximum DOD	Charge rate	Discharge rate
a	SOC adjustment	15°C	-	0.2 CA	-
b	Discharge in the sunshine area	40°C	60	0.025 CA	0.052 CA
c	Discharge in the shadow	-40°C	60	0.025 CA	0.048 CA ~0.052 CA
d	Discharge in the sunshine area	40°C	60	0.025 CA	0.048 CA
e	Waiting in the sunshine area	40°C	-	-	-

Temperature and current profiles of the one day on the Moon (1 set)

# Operational simulation test (Reference)



Cell voltage profiles of DAY 1 and DAY 24



Full capacity change caused by operational simulation test

# Environmental performance

## Vibration test condition

### (a) Sine

Frequency/ Hz	Level
5 to 27.9	6.4 mm (Single amplitude)
27.9 to 100	20 g

Sweep rate: 2 oct / minutes

### (b) Random

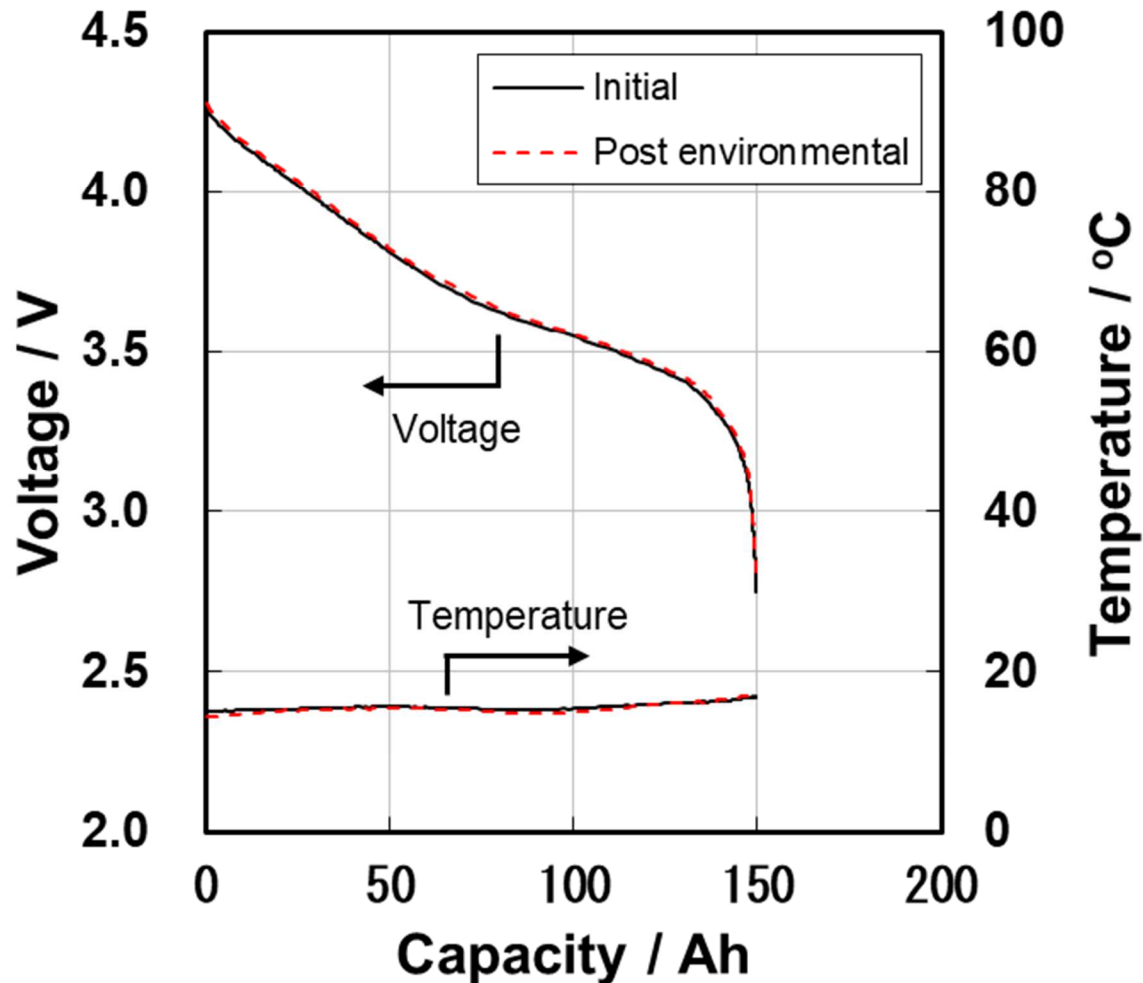
Frequency / Hz	Level	Grms
20 to 58	+6 dB/octave	23.63
58 to 700	0.5 g <sup>2</sup> /Hz	
700 to 2000	-6 dB/octave	

Period: 3 minutes

## Shock test condition

Frequency / Hz	Level
200	40 g
200 to 2000	+9.3 dB/octave
2000 to 7000	1400 g

# Post environmental discharge performance



Post environmental discharge performance of LFR145ex EM cells

✓ The cells passed all the environmental tests.

# Summary

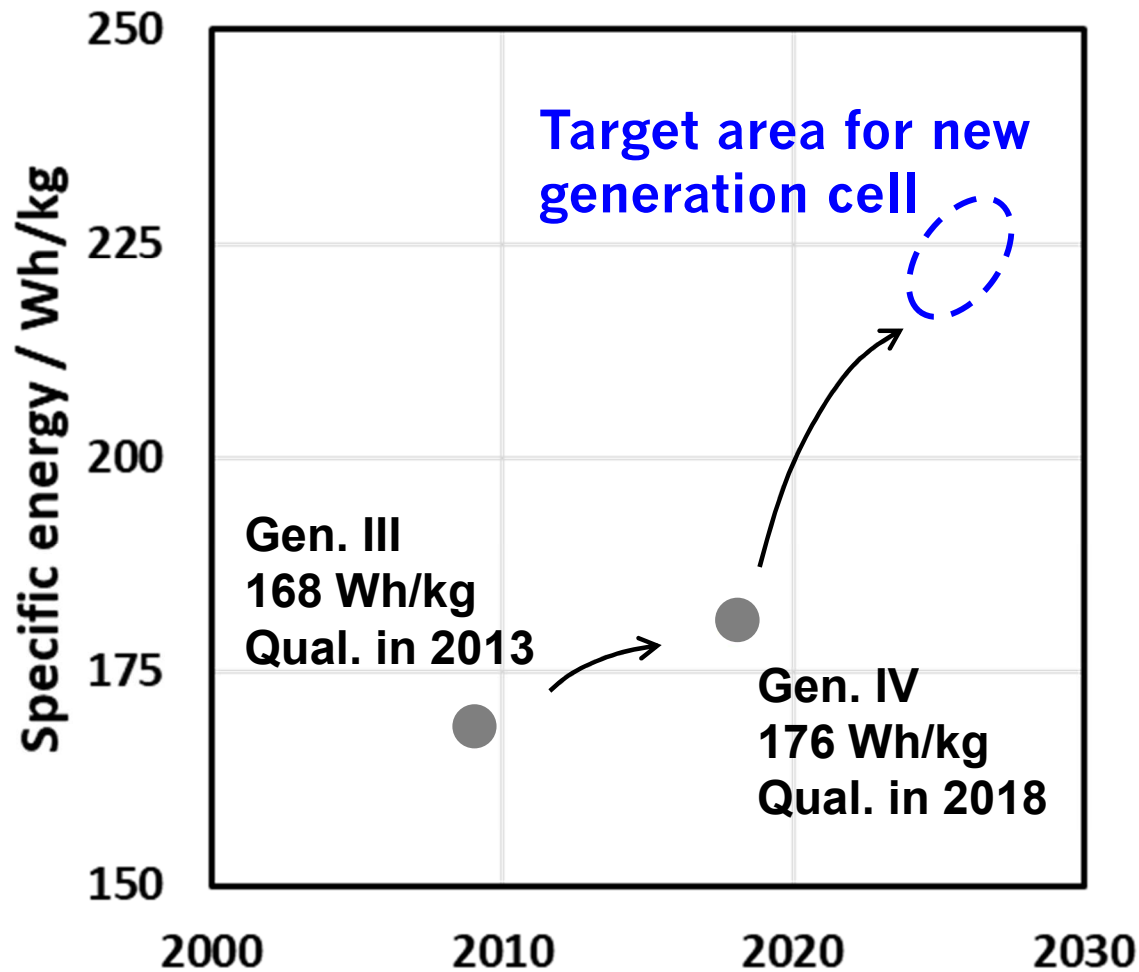
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- ✓ **LFR145ex EM cells have shown a specific energy of 220 Wh/kg by using the chemistry of NCM/Gr with SiO.**
- ✓ **In addition, it demonstrated an excellent life performance up to 800 cycles.**
- ✓ **The cells passed mechanical environmental tests.**
- ✓ **Cell qualification will be carried out based on the plan of JAXA's program.**

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# Development status of the new generation cells for satellite

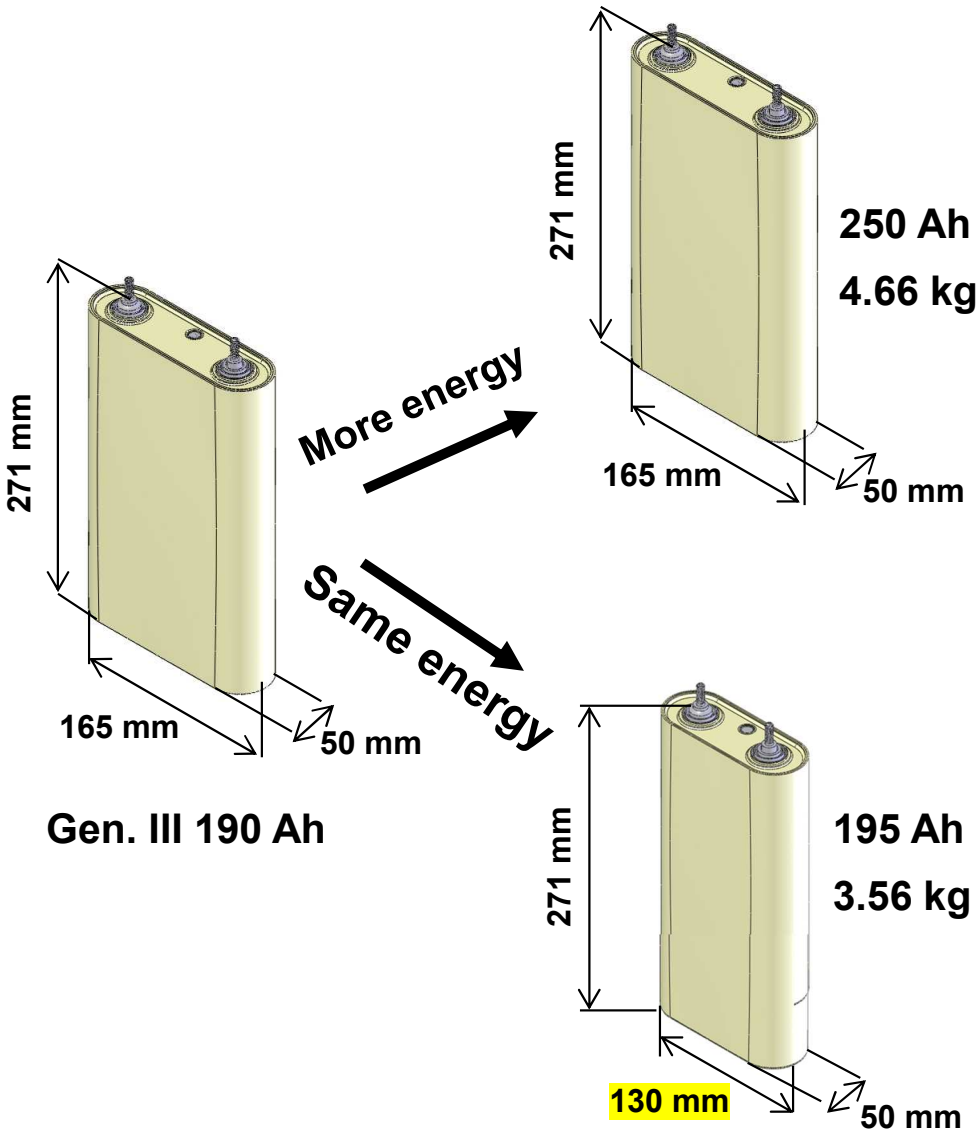
# Target Specifications of new generation cells



Roadmap for development of satellite cells

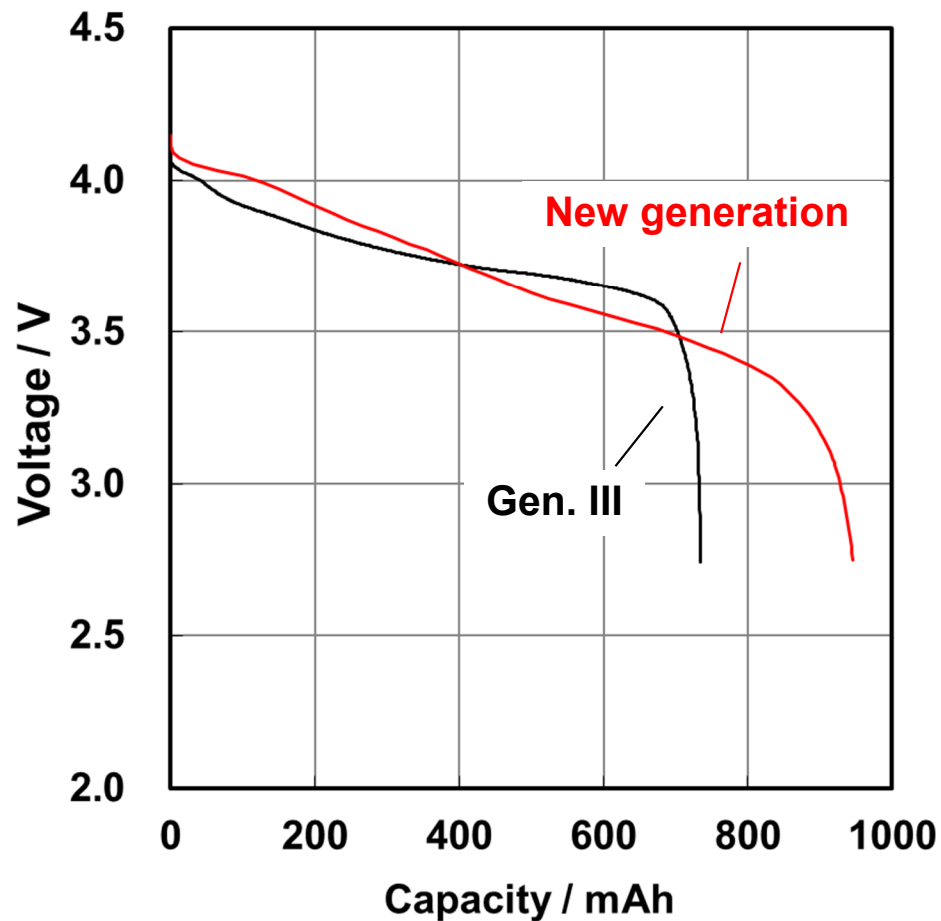


# Target Specifications of new generation cells



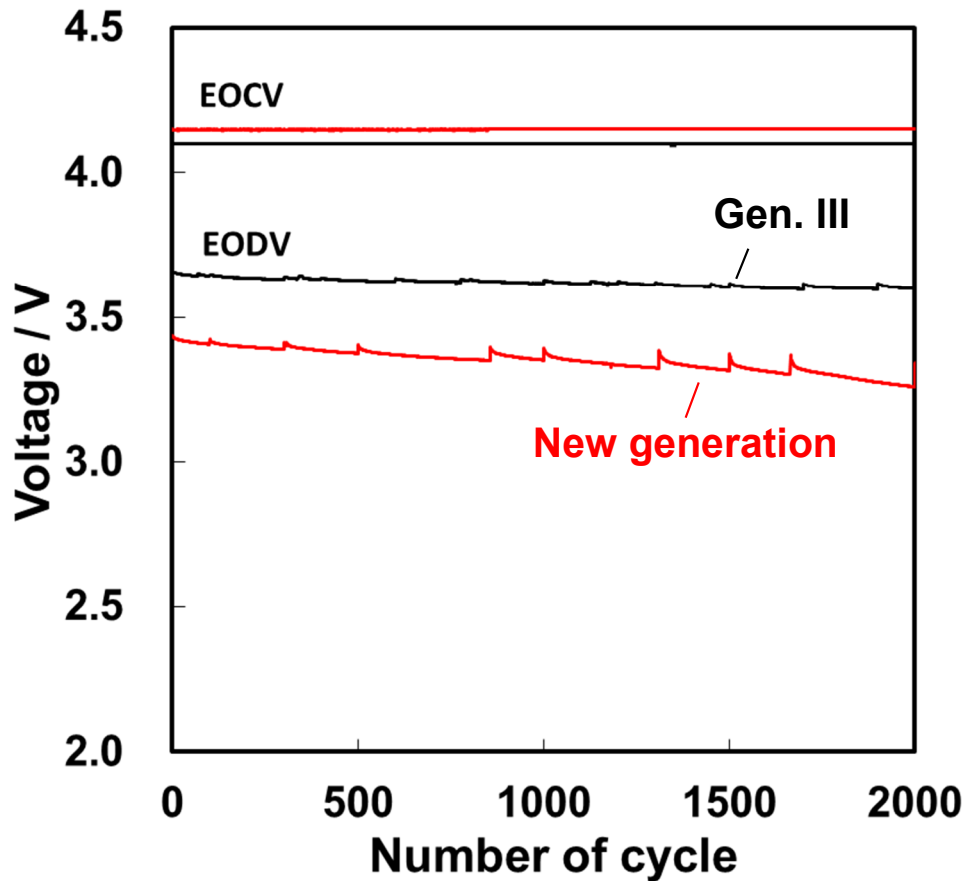
Items	New generation cells		Gen. III
	195 Ah size	250 Ah size	190 Ah size
Chemistry	NCM / Gr+SiO		LCO/Gr
Rated capacity / Ah	C/5 : 203 C/2 : 195	C/5 : 258 C/2 : 250	190
Actual capacity / Ah	C/5 : 225 C/2 : 217	C/5 : 287 C/2 : 277	205
EoCV/ V	4.15		4.10
Discharge Voltage / V	C/5 : 3.67 C/2 : 3.66		3.70
Mass / kg	3.56	4.66	4.59
Specific energy / Wh/kg	C/5 : 232 C/2 : 223	C/5 : 226 C/2 : 218	165

# Discharge performance

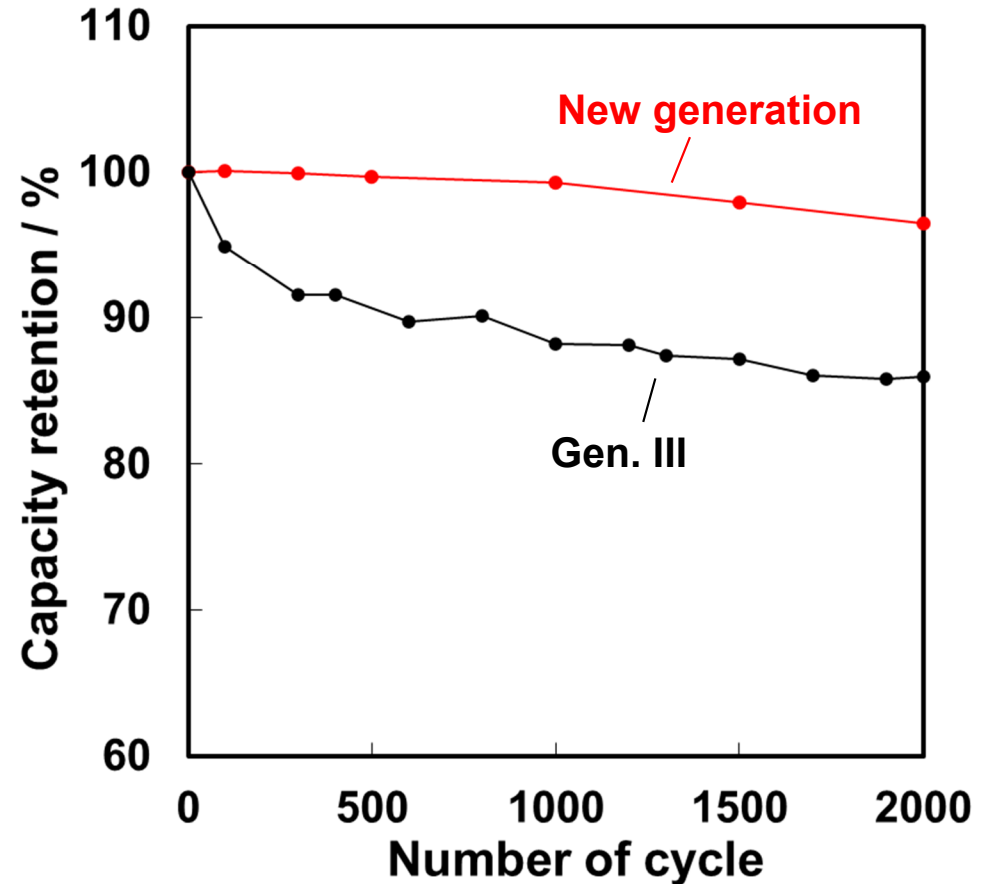


Discharge performance of 1 Ah class new generation cell

# Accelerated GEO life performance



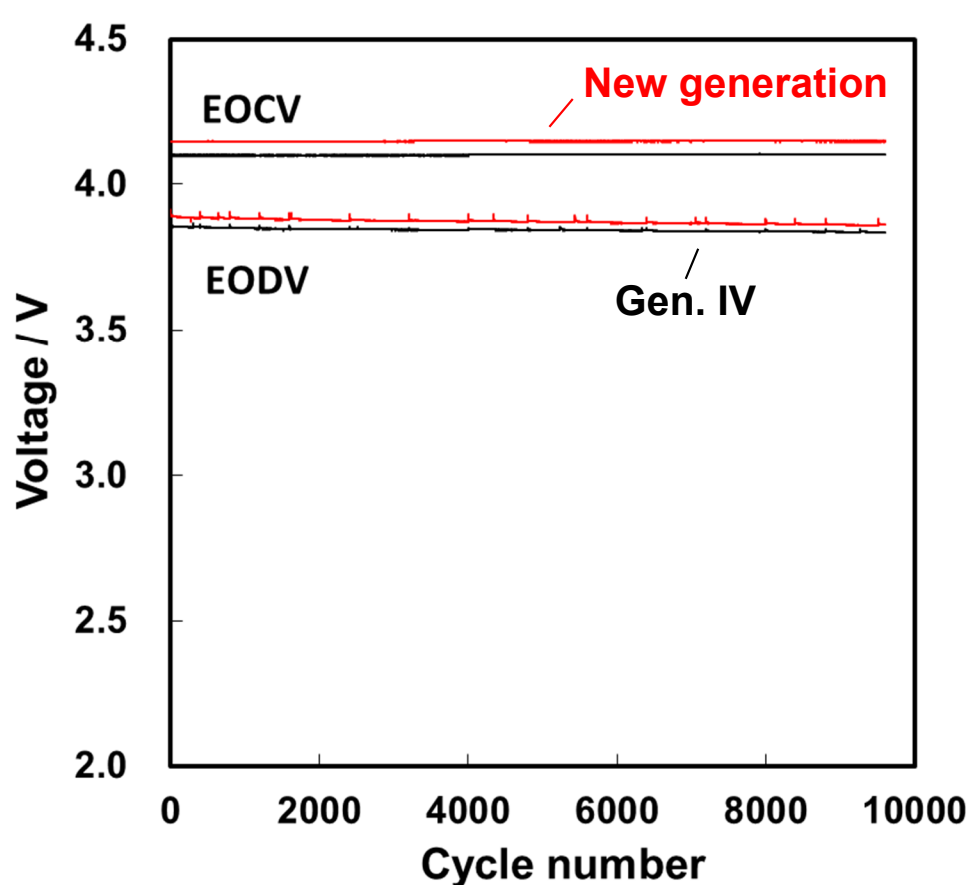
(a) EoCV/EoDV



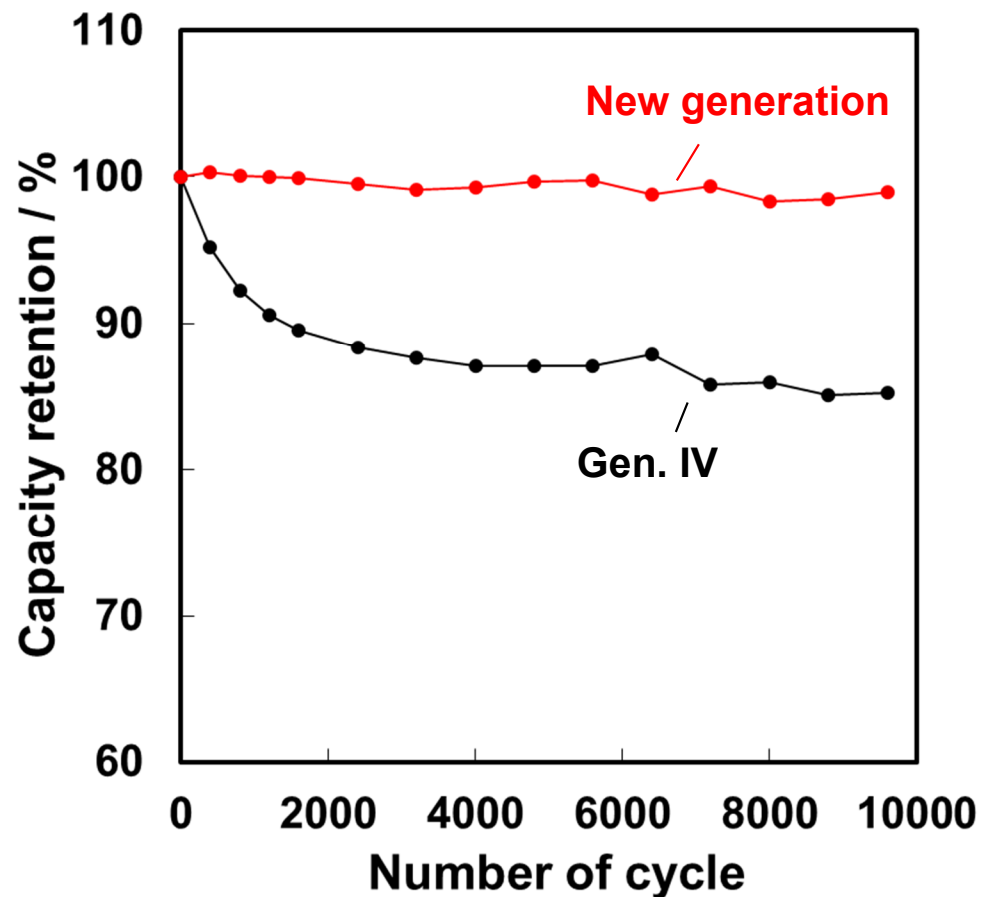
(b) Capacity retention

Continuous DOD 80% cycle life performance of 1 Ah class new generation cell

# Realtime LEO cycle life performance



(a) EoCV/EoDV



(b) Capacity retention

Continuous DOD 25% cycle life performance of 1 Ah class new generation cell