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Cycle-Life Performance Testing of Lithium-Ion Cells at JAXA

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History of large lithium-ion cells at JAXA

Fiscal year	19 94	96	98	20 00	02	04	06	08	10	12
Flexibility investigation	1.0 Ah-class commercial cells Max. cycle life: LEO 23,000 ↔									
Development Evaluation				10-100 Ah-class space cells Max. cycle life: LEO 55,000, GEO 1,800 ←						
Application								LEO, GEO satellites, HTV, Rockets ←		

HTV: H-II transfer vehicle

Design principle

Active material	Type	Parameter
Cathode	$LiCoO_2$, $LiNi_{1-x-y}Co_xAl_yO_2$	Thickness
Anode	Graphite,	Thickness
Electrolyte	Alkyl carbonate mixed solvent	Additives, composition

Cell Design	Mechanical modification	Safety vent, welding Process

Main tests on going at JAXA

(Tsukuba Space Center)

Sample type		Testing condition	Status
Graphite/ $LiCoO_2$	10 Ah cell	LEO, DOD: 25%,@15ºC	32,500
	40 Ah cell	LEO, DOD: 40%@15ºC	13,000
	50 Ah cell	LEO, DOD: 25% @15ºC 5 year-storaged	9,939
	100 Ah cell	LEO, DOD: 25% @15ºC 100%DOD@25℃	55,000
Graphite/ $LiNi_{1-x-y}Co_xAl_yO_2$	50 Ah cell	GEO, DOD: 80% @15ºC	36 Seasons

Topics in this presentation

(1) Progress in long-term cycle-life testing of lithium-ion cells (batteries) simulated spacecraft operation

(2) High-rate design with thin electrode layer for LEO applications

(3) Performance comparison of lithium-ion cells with different electrode materials

(4) Basic properties of higher energy density design (200Wh/kg) cell

(1) Typical life performance

100-Ah cell with graphite anode and $LiCoO_2$ cathode

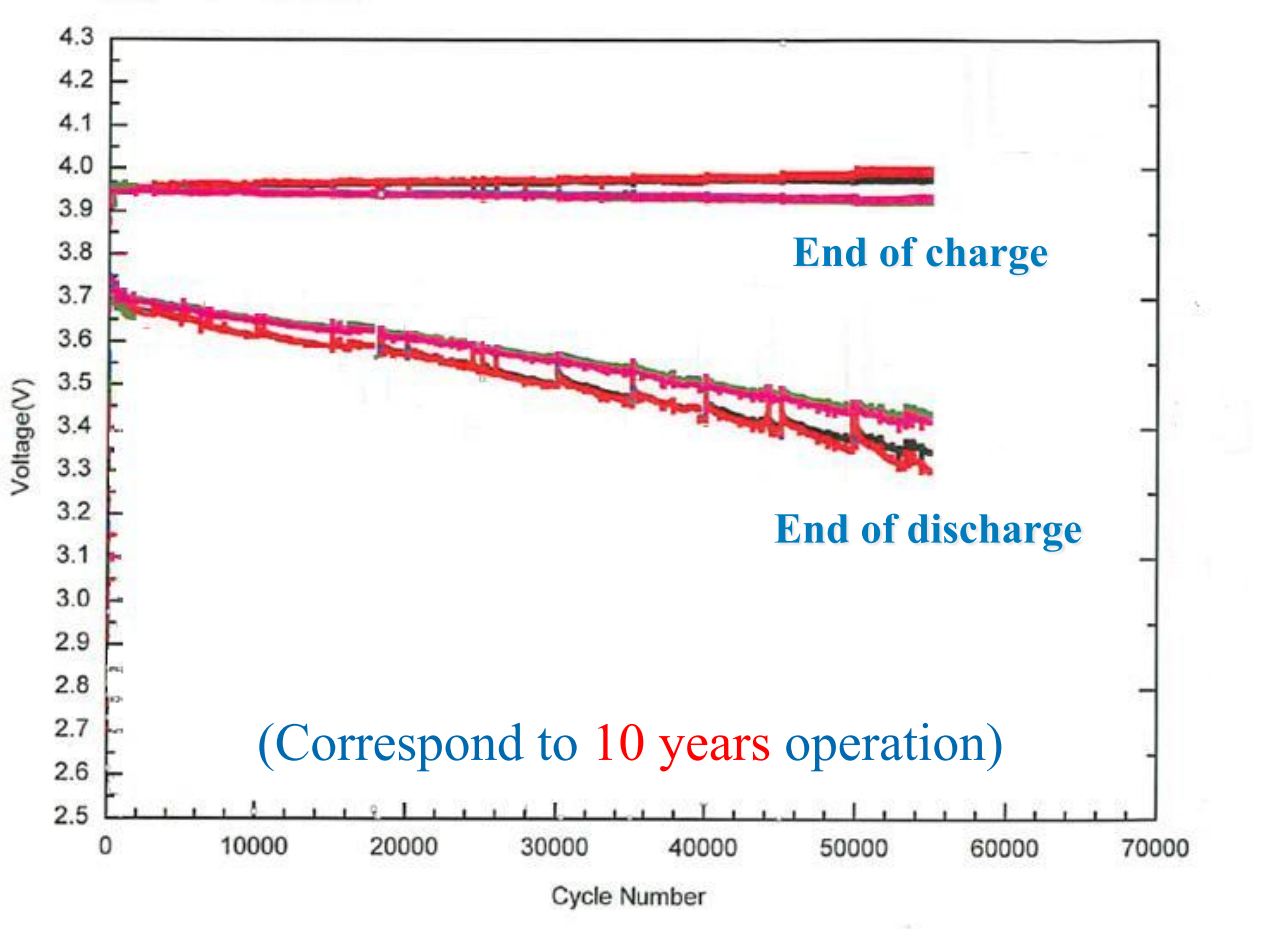
Manufactured by
GS-Yuasa Technology Ltd.

Cell type		Elliptic cylinder
Cathode		$LiCoO_2$
Anode		Graphite
Capacity	Rated	100
	Nominal	110
Nominal voltage, V		3.7
Weight, g		2,800
Dimensions, mm	Width	50
	Length	130
	Height	208
Energy density*	Wh/kg	132
	Wh/l	273

*Calculated using rated capacity

(1) Typical life performance

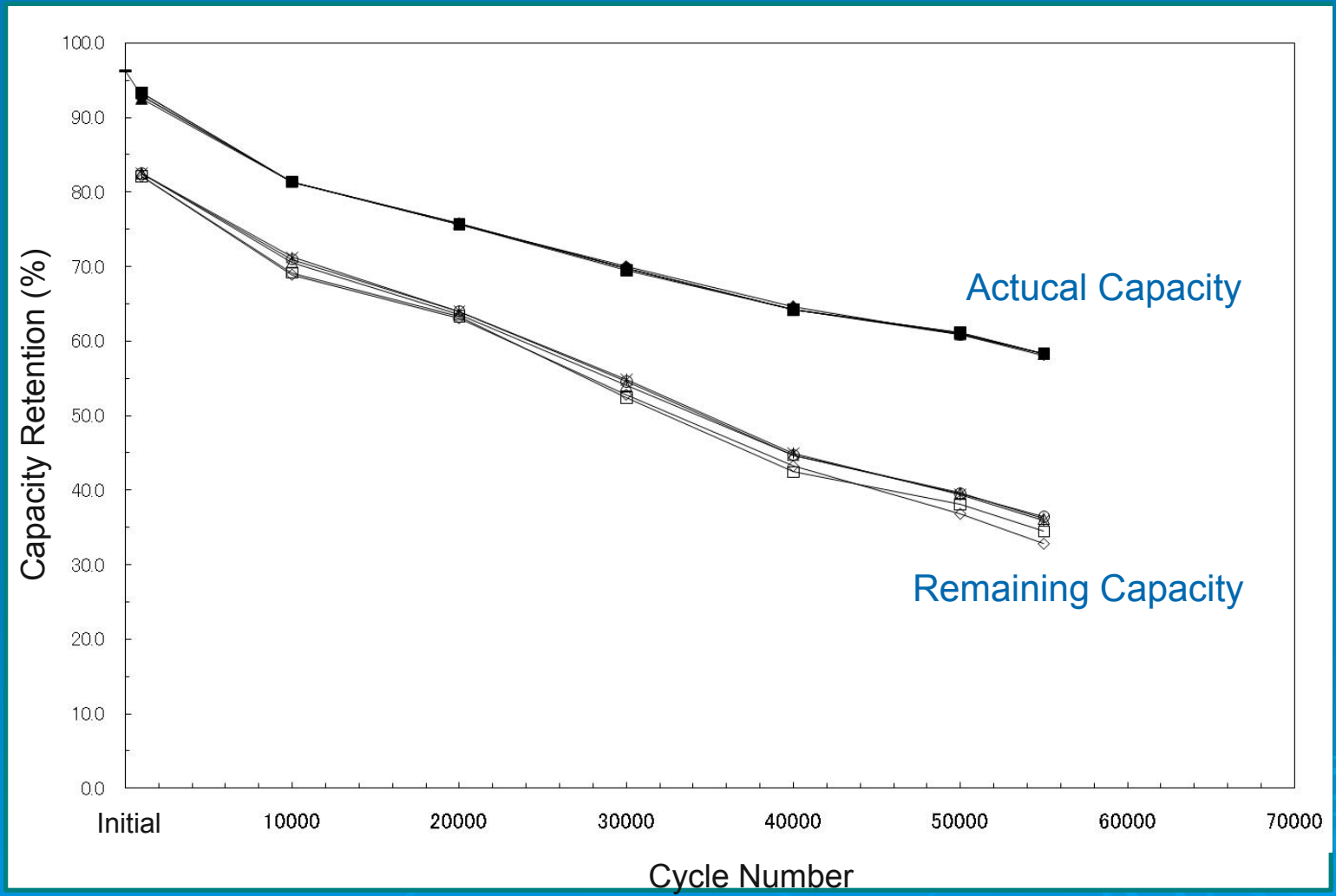
LEO simulation testing: DOD25%



Discharge ---- CC: 50 A (0.5C), 30min.（DOD25.0%）
Charge ----- CC-CV: 30 A (0.3C), 3.95 V, 60min.
Ambient temp. ------- 15 degree-C
5 cells in series

(1) Typical life performance

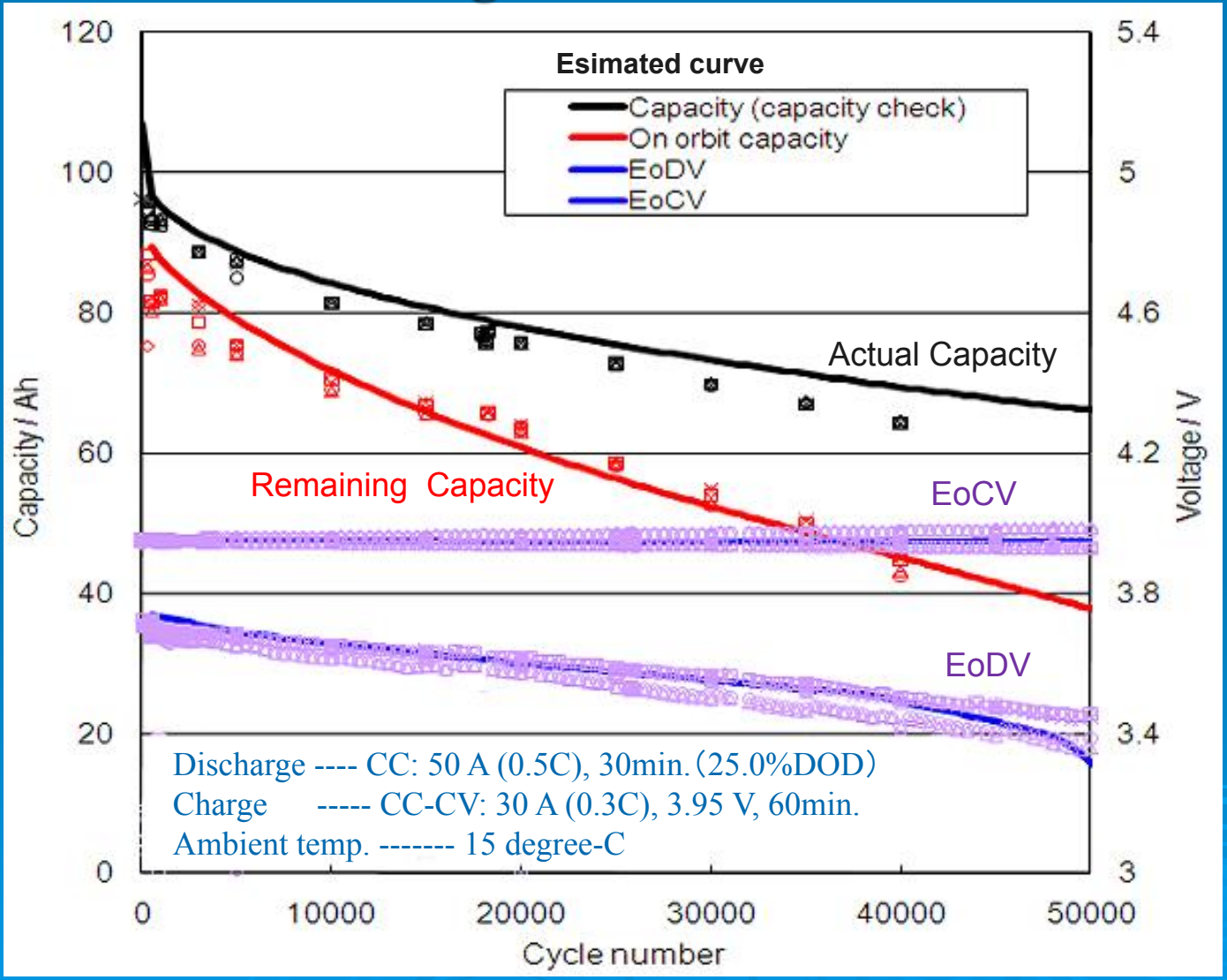
LEO simulation testing: DOD25%



Capacity retention

(1) Typical life performance

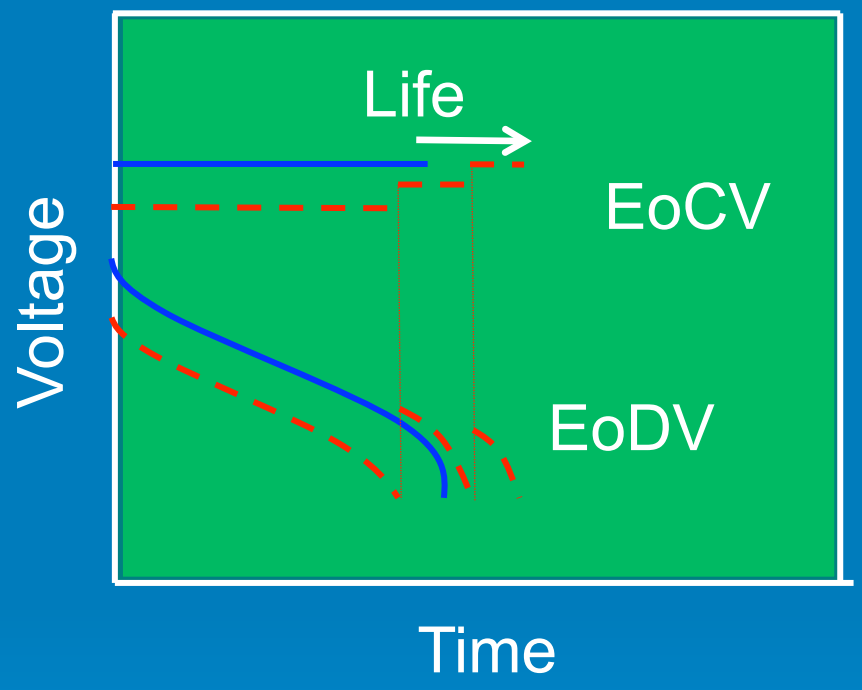
LEO simulation testing and estimatation : DOD25%

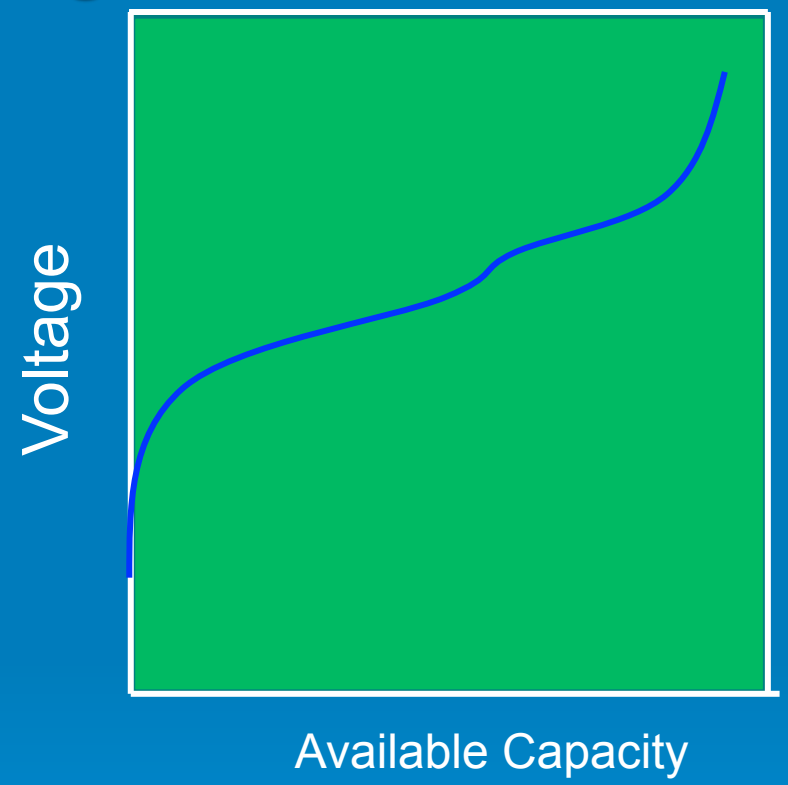


The estimation curve shows good fitting to the test data

(1) Typical life performance

LEO simulation testing: 25% DOD





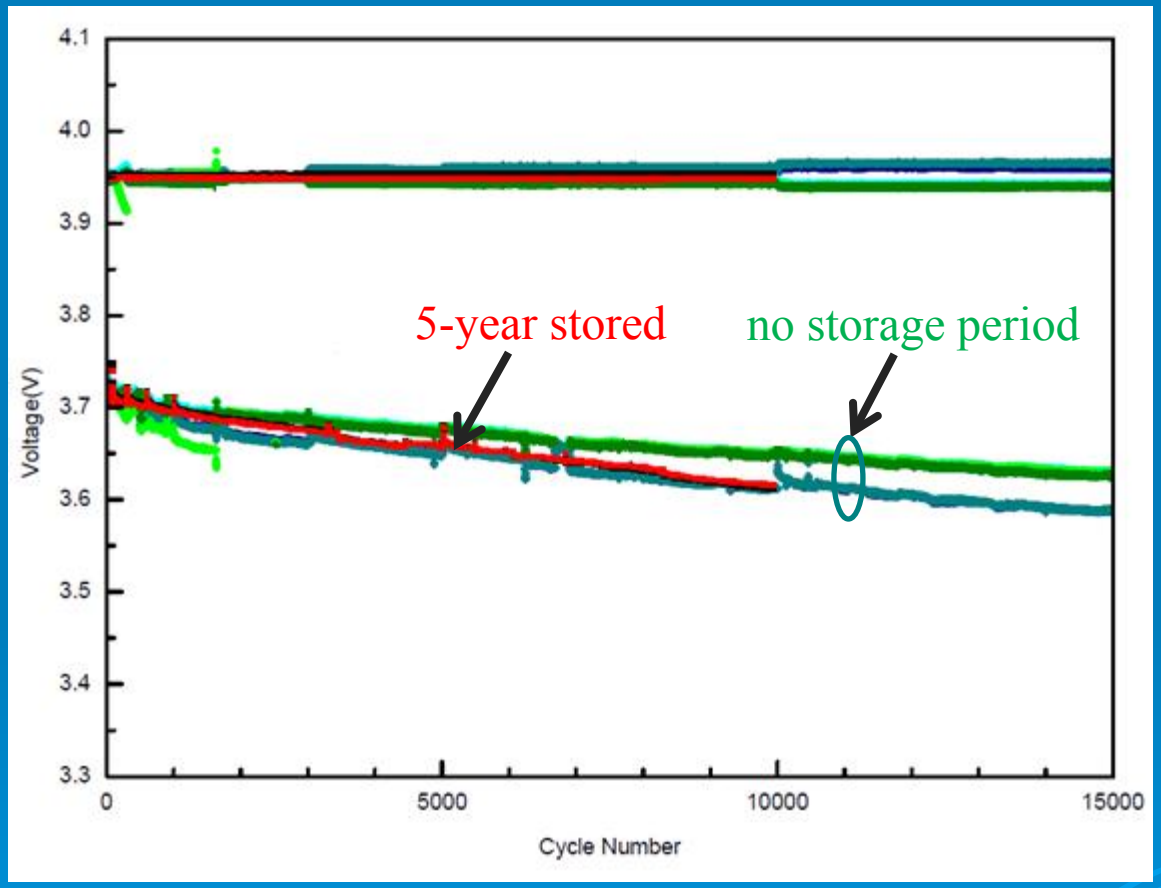
To achieve longer life

Charging voltage should be lower at early stage, and change to higher level

After 55,000cycle, Charging voltatge shifts to 4.0V/cell.

(1) Typical life performance

LEO simulation testing after 5-year stored at 0 deg-C



Discharge---- CC: 25 A (0.5C),30min.（DOD25.0%）
Charge ---- CC-CV: 15 A (0.3C), 3.95 V, 60min.
Ambient temp ----- 15 deg-C
2 cells in series

(1) Typical life performance

Summary

Large Lithium-ion cells evaluated at JAXA
with $LiCoO_2$ cathode and graphite anode

Meet the general requirements for LEO (and GEO) missions

1) high voltage retention
2) small cell voltage dispersion
3) low cell-temperature rising

(2) High-rate design

Design concept

Impedance increase with cycling is responsible for performance fading of a lithium-ion cell with $LiCoO_2$ cathode in our know-ledge. To improve cycle-life performance of the cell, we should suppress cell impedance by

- increasing electrode surface area
- decreasing electrode thickness.

(2) High-rate design

40-Ah cell with graphite anode and $LiCoO_2$ cathode: thinner and larger electrode layer than that of 100-Ah cell

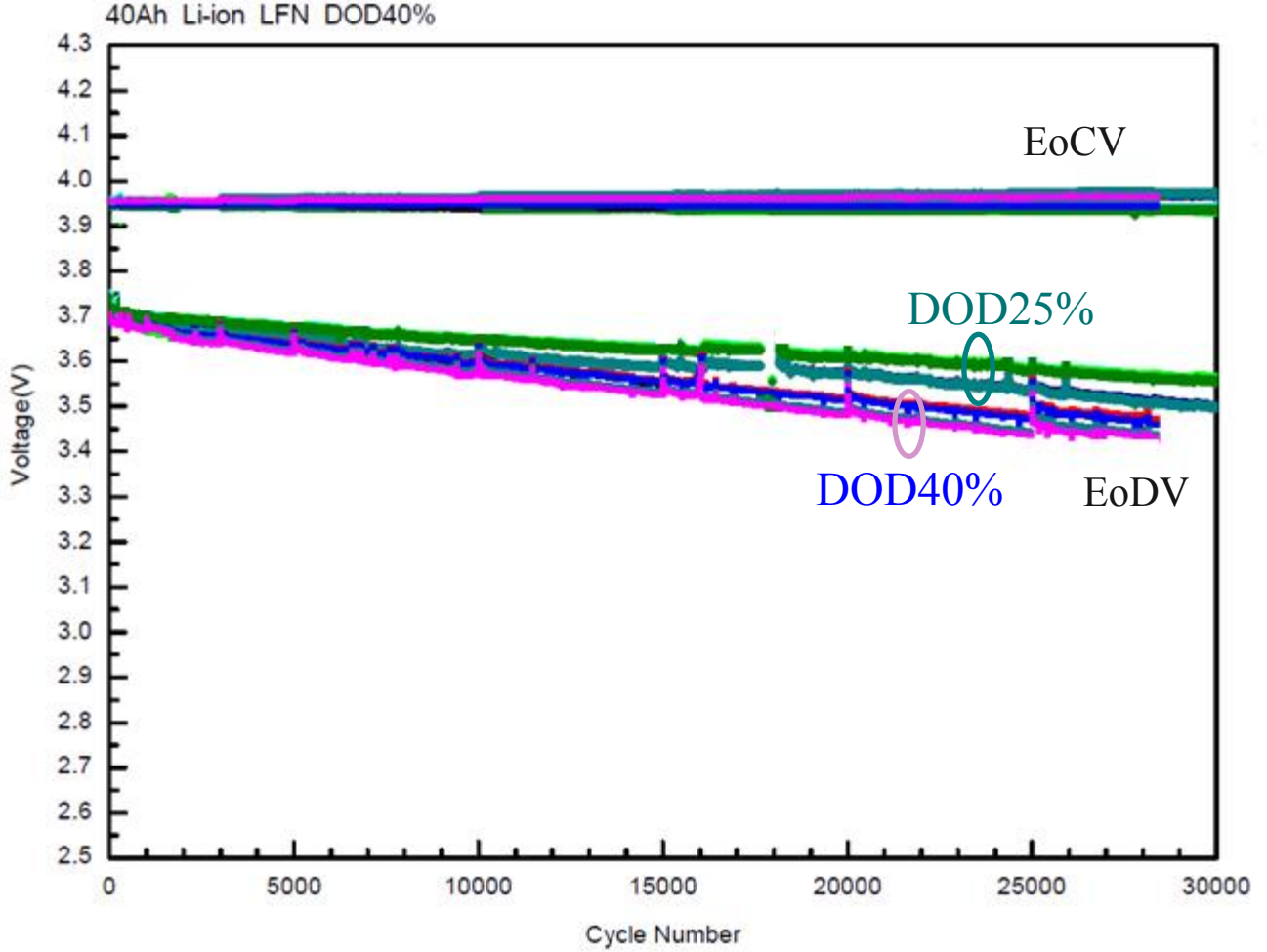
Manufactured by
GS-Yuasa Technology Ltd.

Cell type		Elliptic cylinder
Cathode		$LiCoO_2$
Anode		Graphite
Capacity	Rated	40
	Nominal	45
Nominal voltage, V		3.7
Weight, g		1,500
Dimensions, mm	Width	50
	Length	130
	Height	123
Energy density	Wh/kg	111
	Wh/l	

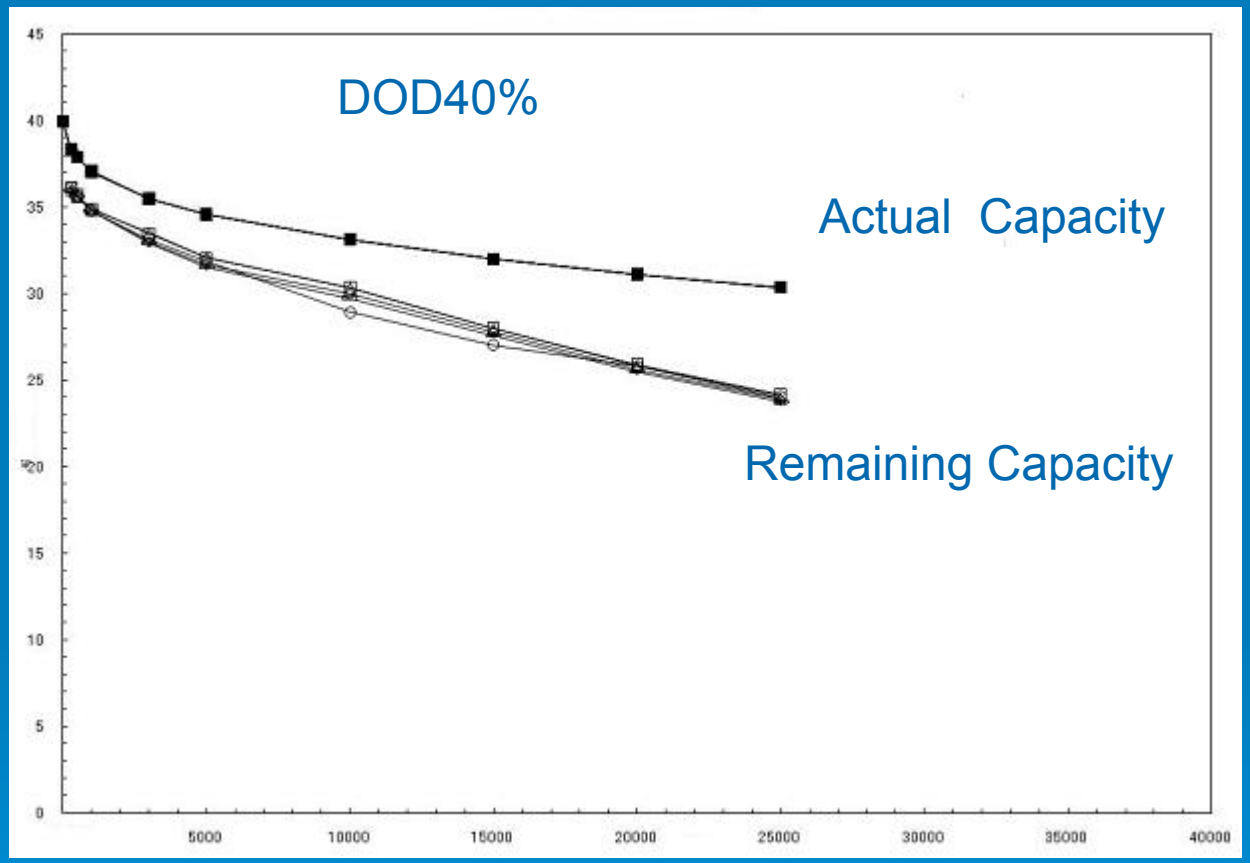
(2) High-rate design

LEO simulation testing: DOD40%

Ambient temp. 15°C, taper voltage 3.95 V



(2) High-rate design



Capacity retention

(2) High-rate design

Summary

High-rate designed lithium-ion cells
with $LiCoO_2$ cathode and graphite anode

Promising for LEO operation
due to lower impedance compared with that of standard cell and slow impedance increase with cycling

(3) Alternative cathode materials

50-Ah cell with graphite anode and $LiNi_{1-x-y}Co_xAl_yO_2$ cathode

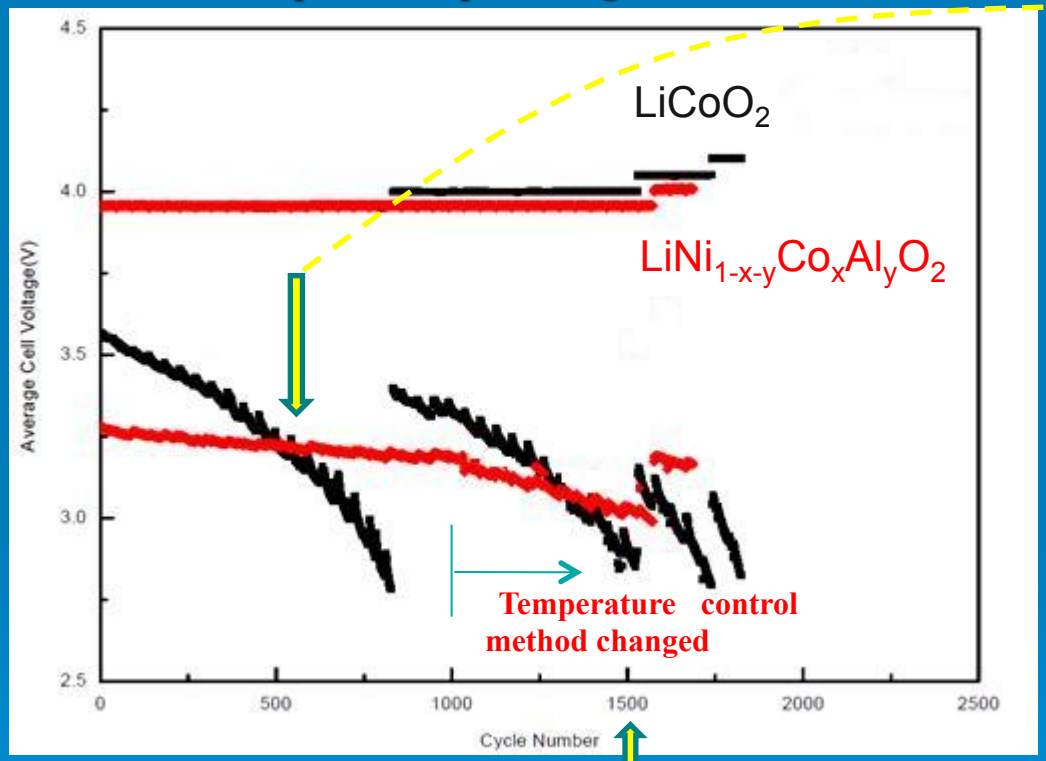
Manufactured by
GS-Yuasa Technology Ltd.

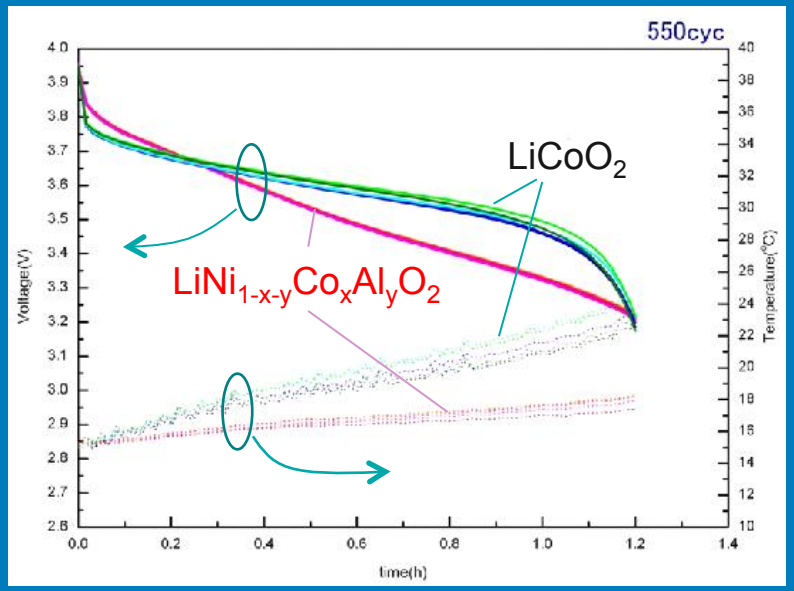
Cell type		Elliptic cylinder
Cathode		$LiNi_{1-x-y}Co_xAl_yO_2$
Anode		Graphite
Capacity	Rated	50
	Nominal	53
Nominal voltage, V		3.6
Weight, g		1,400
Dimensions, mm	Width	52
	Length	130
	Height	123
Energy density	Wh/kg	136
	Wh/l	254

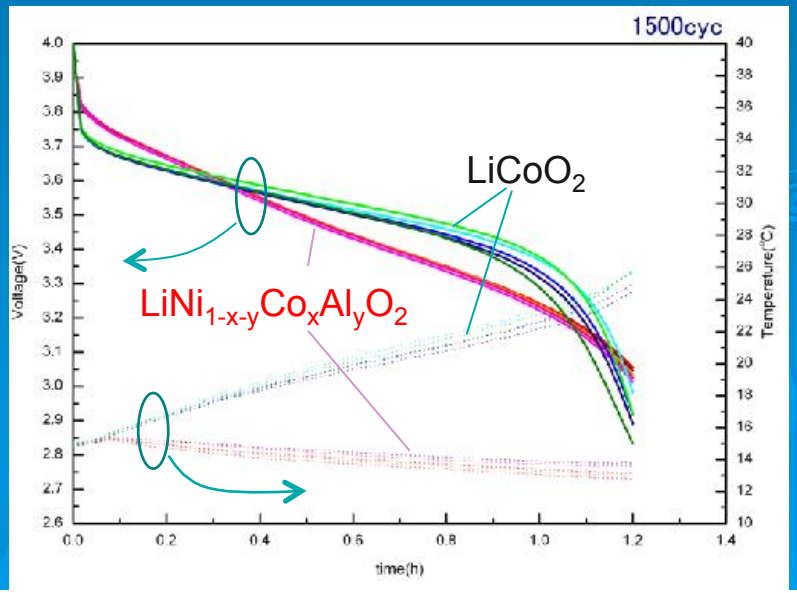
(3) Alternative cathode materials

GEO simulation testing: DOD80%

Ambient temp. 15°C, taper voltage 3.95 V

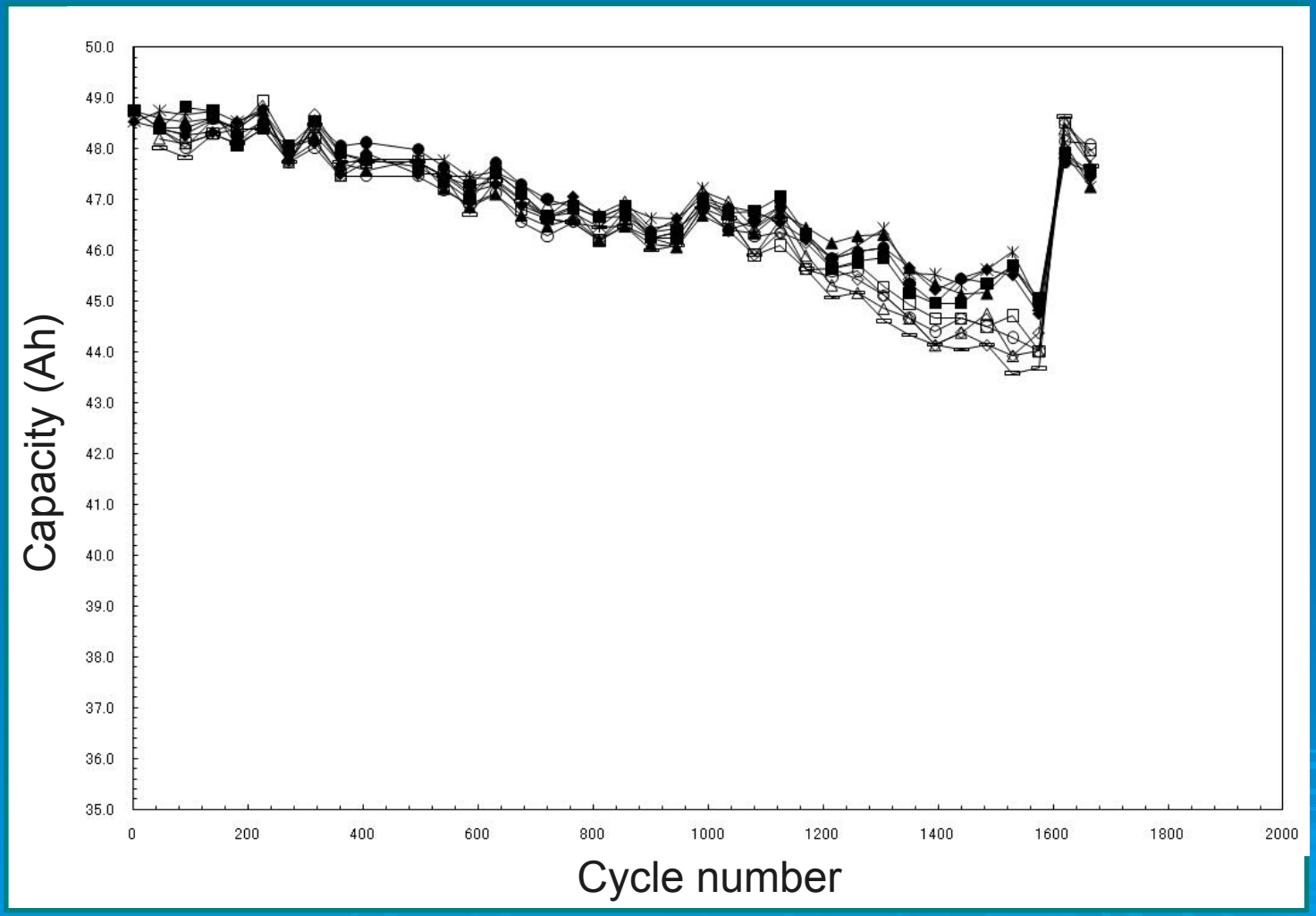






(3) Alternative cathode materials

GEO simulation testing: 80% DOD



Capacity-retention

(3) Alternative cathode materials

Summary

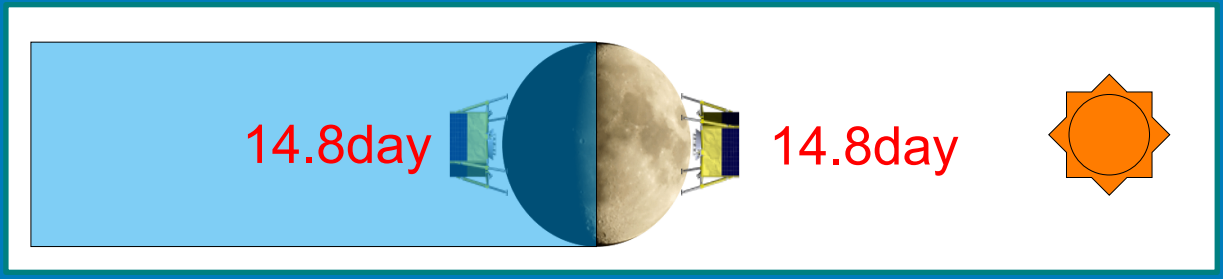
Lithium-ion cells

with $LiNi_{1-x-y}Co_xAl_yO_2$ cathode material

Expected to be a candidate for one of the alternative of $LiCoO_2$ cathode for GEO mission

(4) Higher energy density cell

Very light weight cell are required for Lunar and other exploration missions



Item		Requirements
energy Density		>250 Wh/kg
Chg/Dchg rate		up to 0.2C
Temperature range	Charge	20-50 deg-C
	Discharge	-20-50 deg-C
Duretion of cycle		100 cyc
Duration of life		2 year

(4) Higher energy density cell design

1st Stage trial

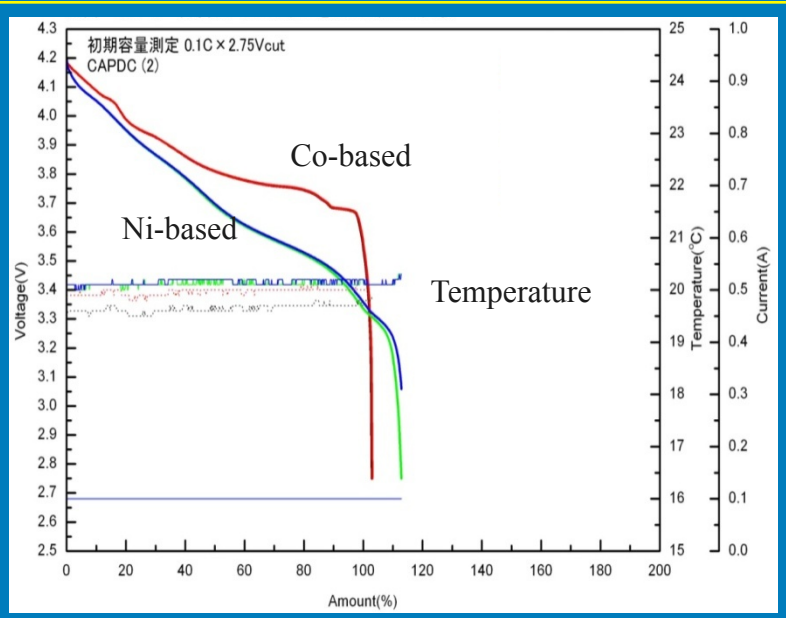
Preliminary design and test production using COTS cell

Manufactured by GS-Yuasa Technology Ltd.

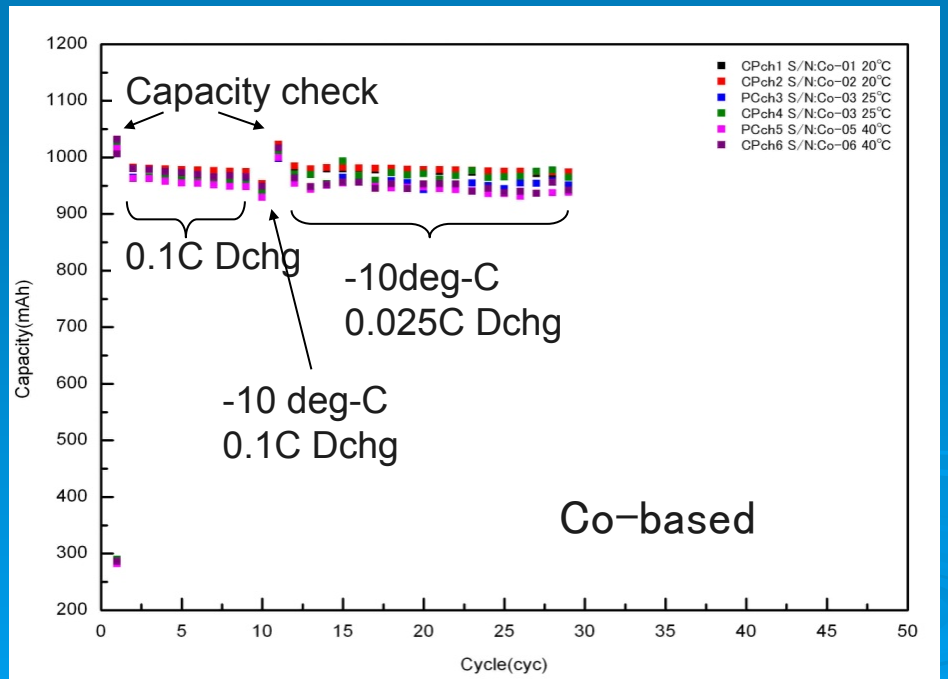
	Type A	Type B
Cathode	Co-based	Ni-based
Anode	Graphite	Graphite
Capacity	1.052Ah	1.132Ah
Dimension (terminal not included)	L 49.3mm x H 33.7 mm x D 5.17mm	
Geometry	Prismatic	
Weight	20.9 g	20.0 g
Energy Density	186 Wh/kg	209 Wh/kg

(4) Higher energy density cell design

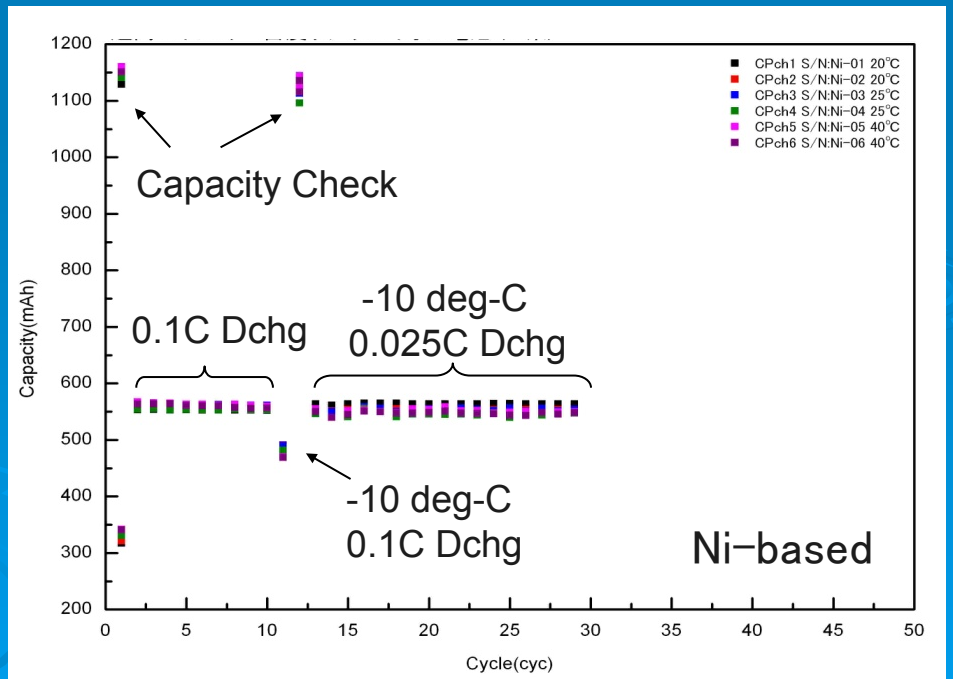
Capacity check (2.75V cut off)



3.6V cut off



3.6V cut off



(4) Higher energy density cell design

2nd Stage trial

Cell producted using the same process with the large scale Li ion cells production.

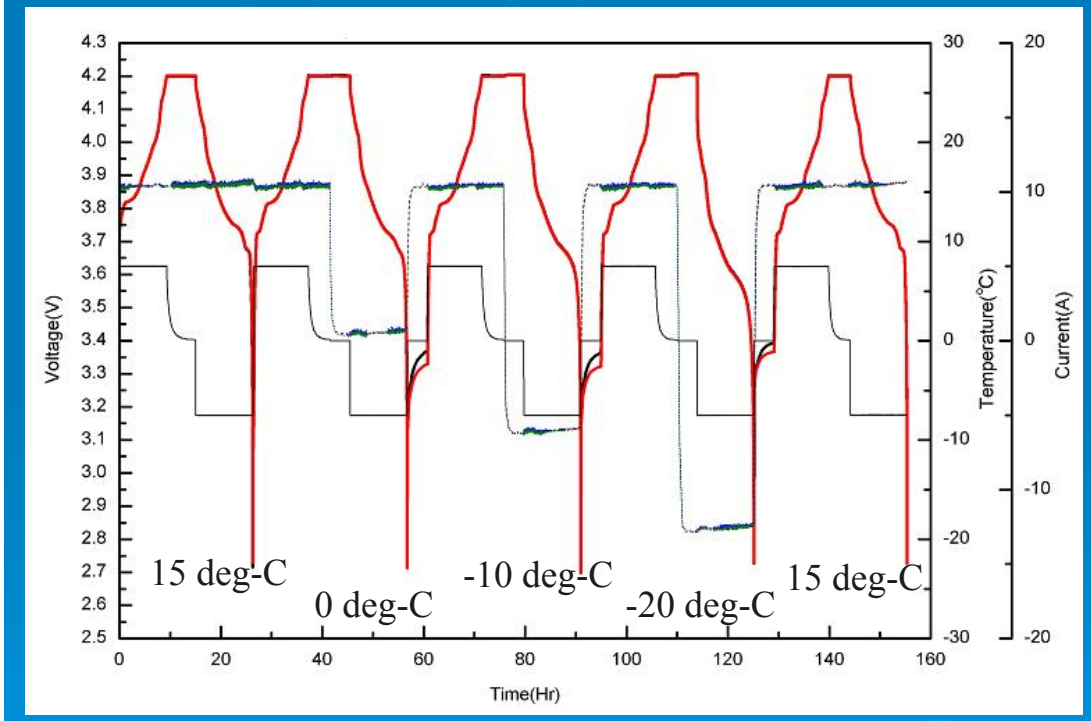
Requirement of energy density is relaxed because of the first approach for this production.

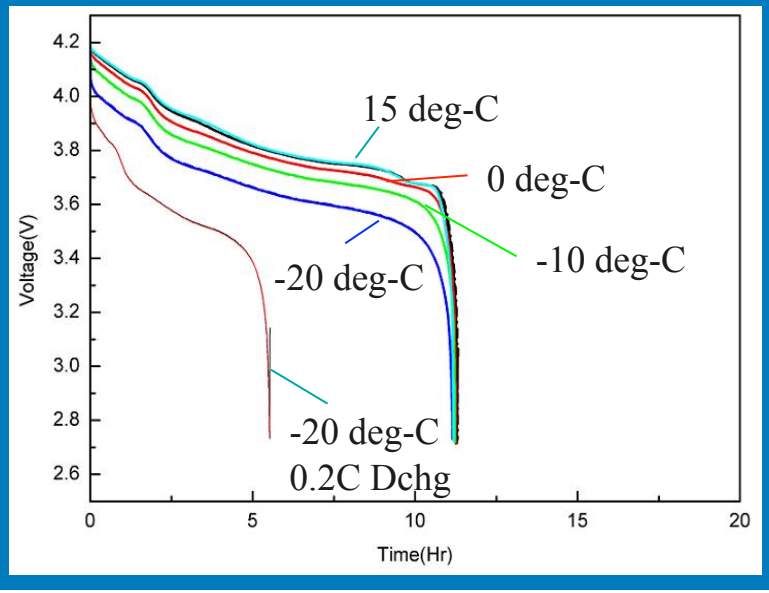
Item	Performances
Cathode	Co-based
Anode	Graphite
Capacity	56Ah
Dimension (terminal not included)	L 98mm x H 159 mm x D 37.0mm
Geometry	Elliptic Cylinder
Weight	1,130 g
Energy Density	188 Wh/kg

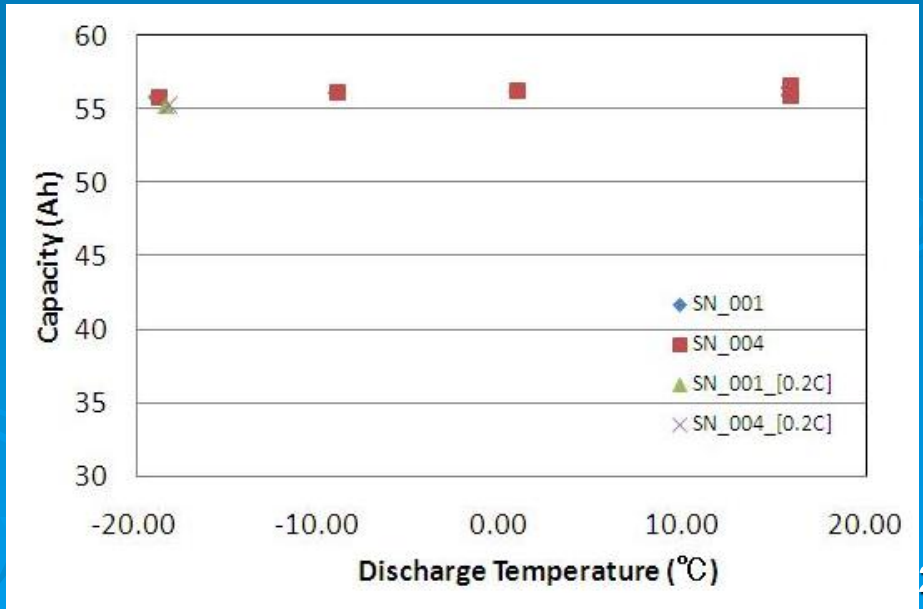
(4) Higher energy density cell design

Capacity check at various discharge temperatures (2.75V cut off)

Charging temperature : 15 deg-C
Charging/discharging rate : 0.1C







(4) Higher energy density cell design

Summary

Lithium-ion cells

designed for having higher energy density(>200Wh/kg)

Low rate operations provide equivalent capacity at low temperature.
Improvements of energy density and expand temperature range are in progress.

Prospect

Large capacity Lithium-ion cells

Evaluation for satellite- and rocket-projects at JAXA

(1) Continue on-ground real time cycle-life testing
(2) Optimize the operation conditions in a space environment
(3) Establish database with different electrode materials
(4) Design and development of higher energy density cell for lunar and other exploration missions

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