


How to develop a lithium-ion battery with maximum safety?

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Dangers


- ▶ When packing large amounts of energy in a small volume, there is a risk.
 - Gasoline
 - Chocolate cake –less risky
 - ▶ The risk can not be eliminated, but it can be minimized
 - Good design
 - Careful production
 - ▶ One accident can destroy the market
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Safety is not a joke




UPS Plane destroyed by lithium ion battery fire

Five levels of safety

- ▶ 1. Chemistry
 - ▶ 2. Cell design
 - ▶ 3. Production quality
 - ▶ 4. Battery management system
 - ▶ 5. Fuses, pressure valves etc.
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1. Chemistry

- ▶ Dangerous negative electrode (anode)
 - Lithium metal plating
 - ▶ Dangerous positive electrode (cathode)
 - Collapse of oxide structure
 - Thermal runaway
 - ▶ Dangerous electrolyte
 - Flammability
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Negative electrode (anode)

- ▶ Lithium metal easily gets plated on the surface of graphite
 - Only 80mV potential difference between intercalation and plating
 - Dendrites of metallic lithium can short circuit the cell
- ▶ Lithium titanate negative electrode solves the problem
 - 1550mV potential difference between intercalation and plating
 - 1.4V lower cell voltage
 - (2.3V instead of 3.7V)

Positive electrode (cathode)

- ▶ Lithium cobalt oxide must not be fully charged
- ▶ If overcharged, the crystal structure may collapse and liberate oxygen
 - Oxygen is needed for fire!
- ▶ Lithium iron phosphate can be fully charged
 - Oxygen is never liberated
 - 0,5V lower cell voltage
 - (3.2V instead of 3.7V)

Wrong positive electrode?



Positive electrode (cathode)



Lithium iron phosphate cell after crash test.
Cell voltage before and after test was 3.2V.

Electrolyte

- ▶ Electrolyte solvents are flammable
 - Flashpoint of DMC is 17°C
 - Flashpoint of DEC is 33°C
- ▶ Ionic liquids do not burn
 - Too expensive
- ▶ Flame retardants can be used
 - Do they work?
- ▶ All electrolyte should be absorbed
 - No free flowing liquid
 - Polymer electrolyte

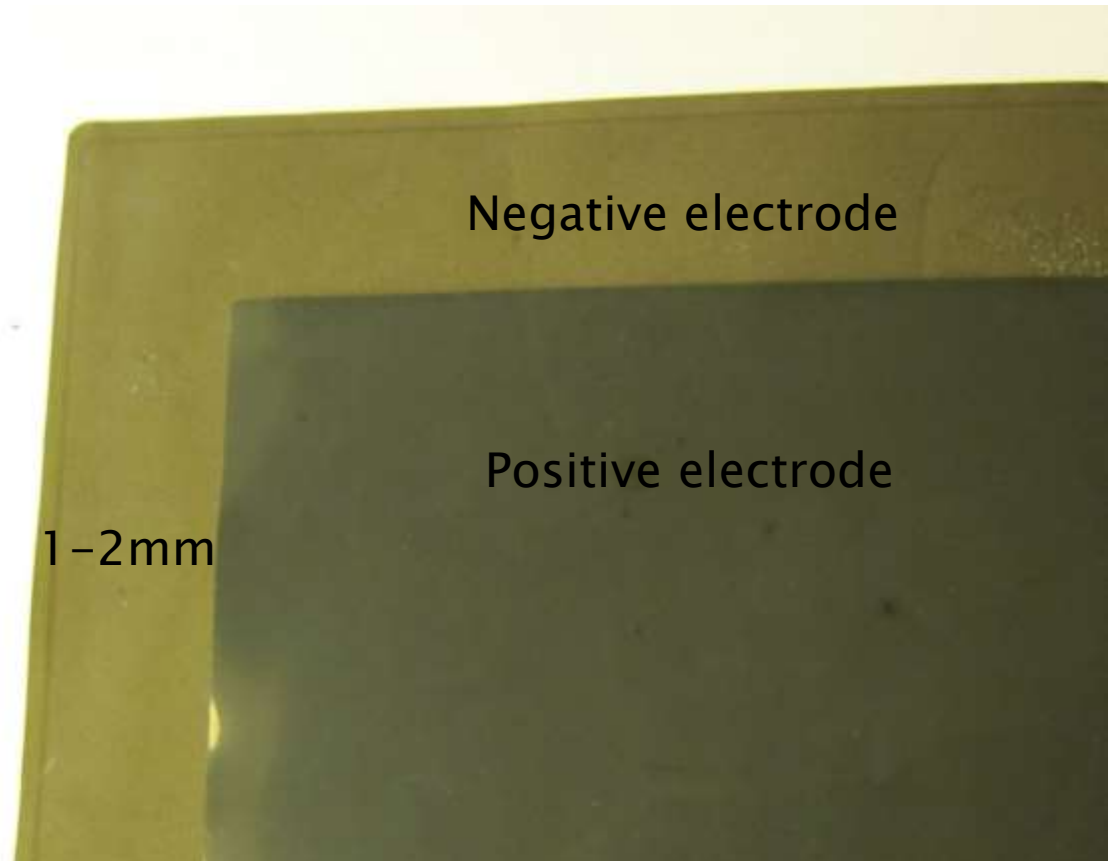
2. Cell design

- ▶ Few large cells or many small cells?
 - Propagation of fire
 - Tesla S (85kWh) has 7104 cells, NCA chemistry!
- ▶ Cylindrical, prismatic or pouch cells?
 - Cylindrical is mechanically strong
- ▶ Aluminum, steel or laminate?
 - Aluminum melts at 660°C



2. Cell design

- ▶ High negative/positive ratio
- ▶ Wide margins on negative edges

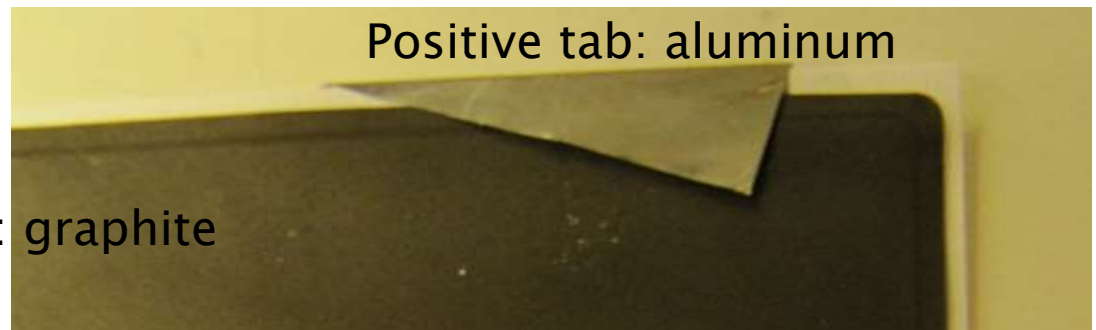


2. Cell design

- ▶ Short circuit must be avoided
 - Positive electrode:
 - Aluminum has very high conductivity
 - Cobalt oxide has low conductivity
 - Iron phosphate has very low conductivity
 - Negative electrode:
 - Copper has very high conductivity
 - Graphite has high conductivity

- ▶ Worst case:

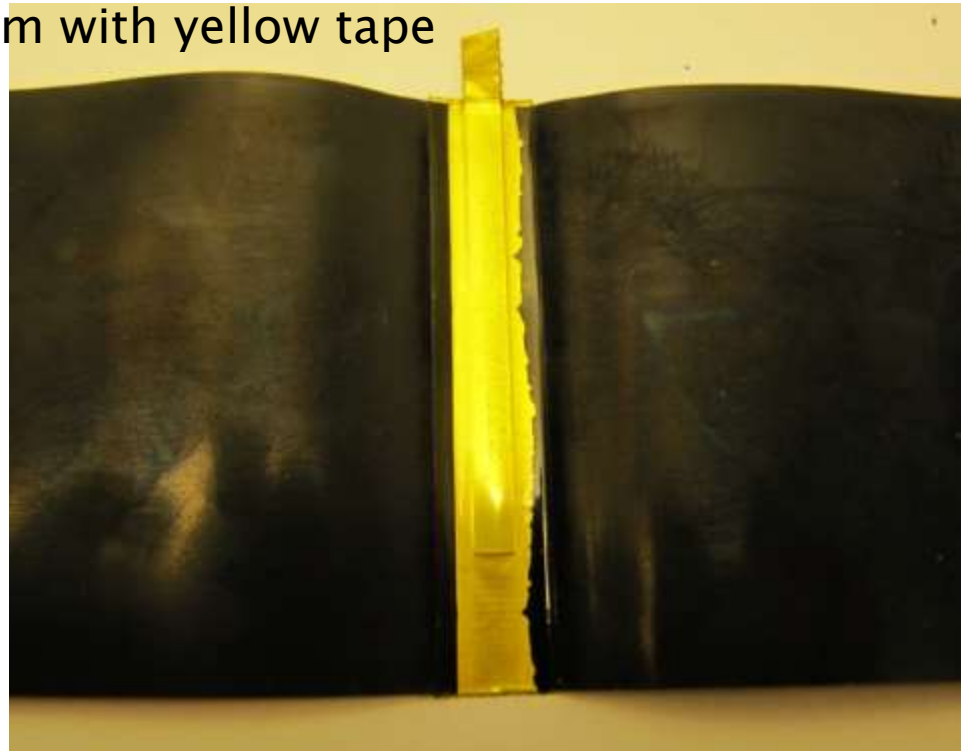
Negative coating: graphite



2. Cell design

- ▶ Aluminum must be well protected
 - Bare aluminum is covered with tape

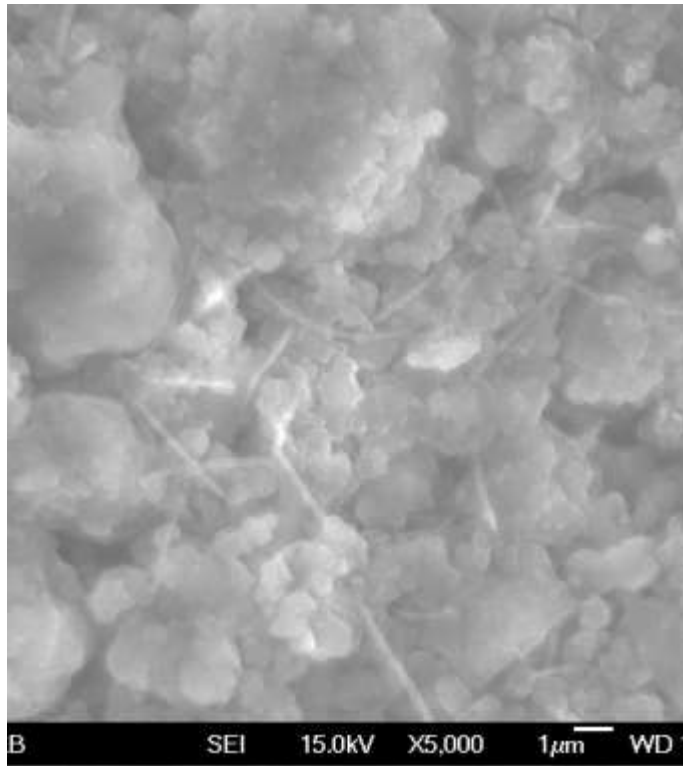
Aluminum with yellow tape



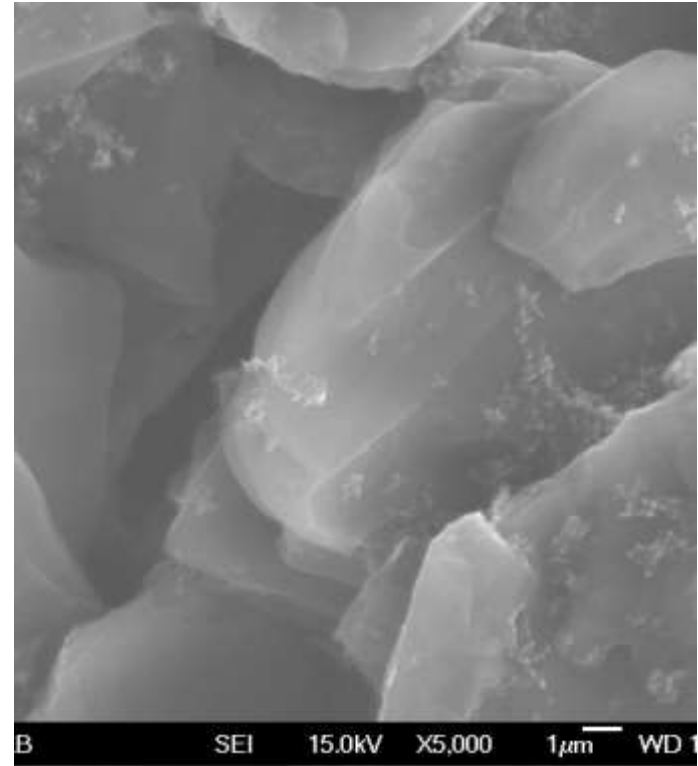
Positive electrode

2. Cell design

- ▶ Power cell or energy cell?




Power graphite



Energy graphite

3. Production quality

- ▶ Careful dust control
 - ▶ Video control
 - ▶ X-ray control

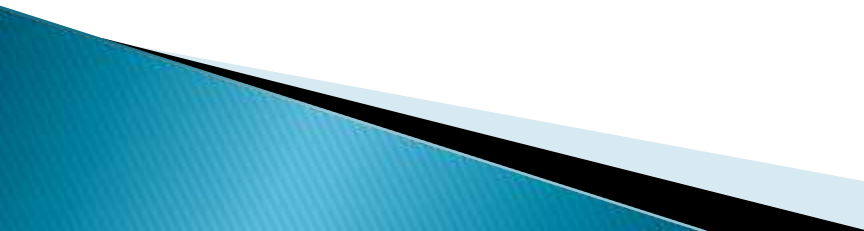
 - ▶ High quality machinery!
 - ▶ Independent quality control people
 - ▶ Company culture
 - ▶ Economical situation of the company
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4. Battery management system

- ▶ Should avoid overcharge
 - ▶ Should avoid overdischarge
 - ▶ Should avoid overheating

 - ▶ by balancing the cells
 - ▶ by restricting the current

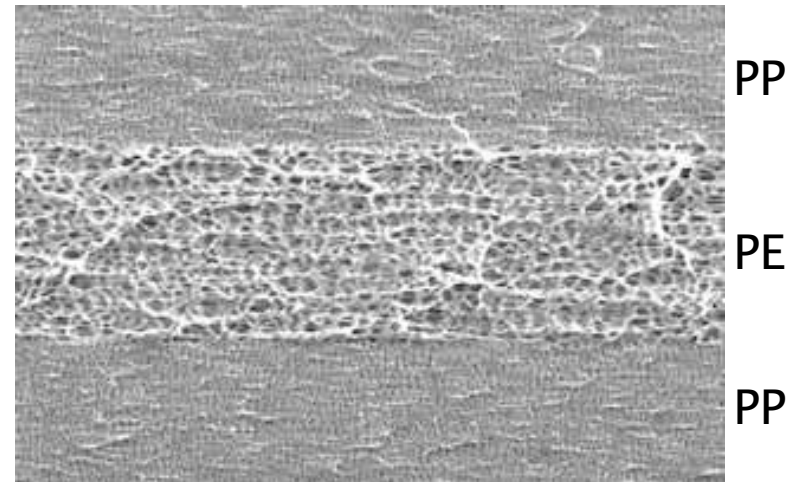
 - ▶ Can it take care of end-of-life?

 - ▶ **KEEP IT SIMPLE and reliable!**
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5. For the worst case

- ▶ Shut-down separator

- For small cells
- 2 x Polypropene
- 1 x Polyethene



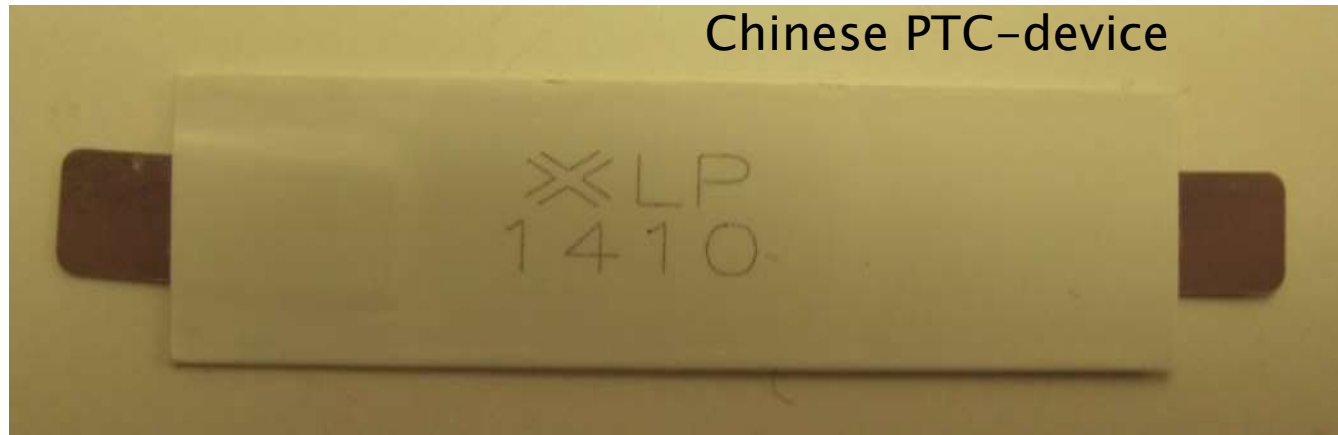
Celgard shut-down separator

- ▶ Ceramic separator

- For large cells
- Al_2O_3 particles
- Expensive


5. For the worst case

- ▶ Fuse
 - PTC-device (positive temperature coefficient)
 - CID (current interrupt device)



- ▶ Pressure valve

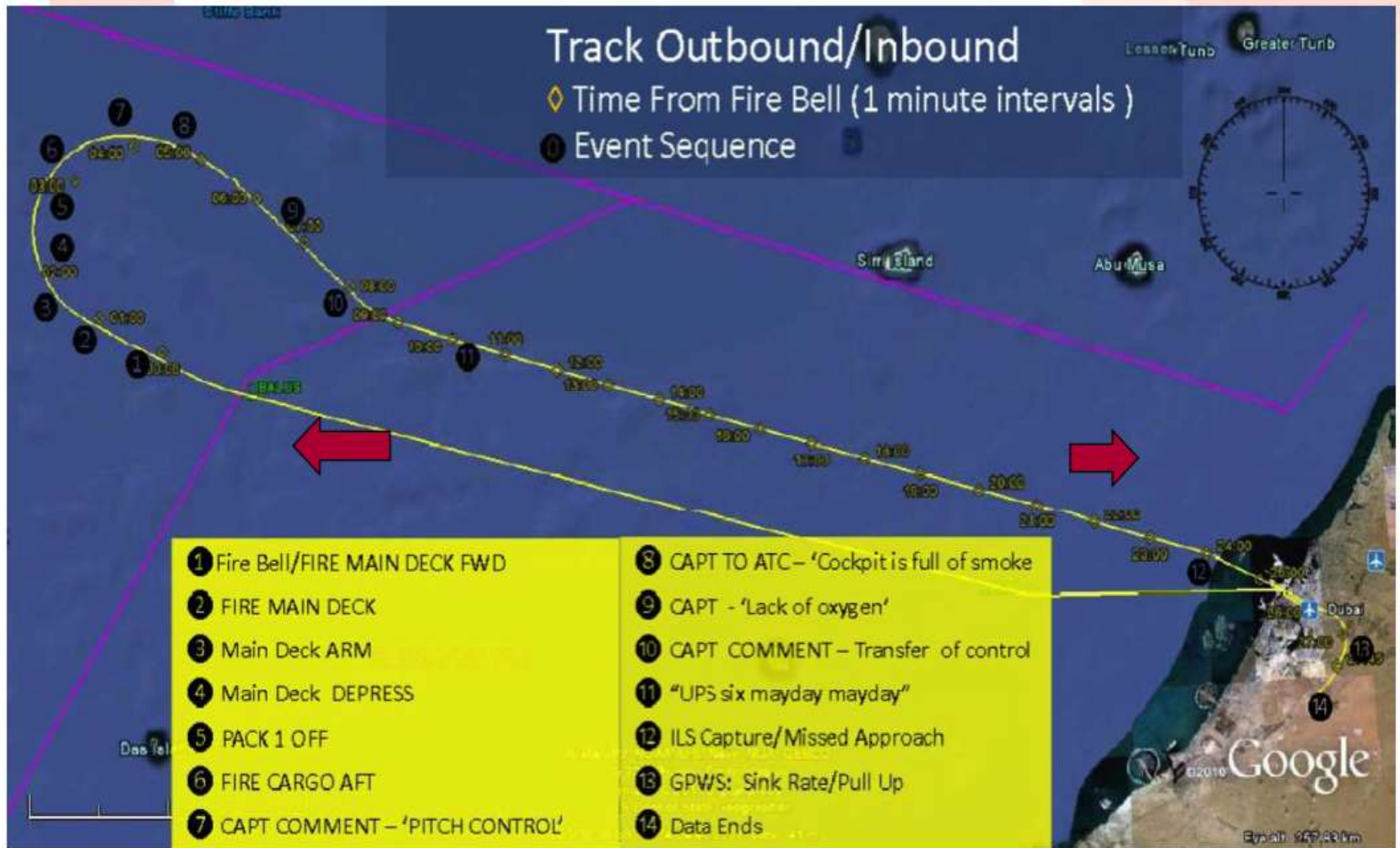
Citius, altius, fortius

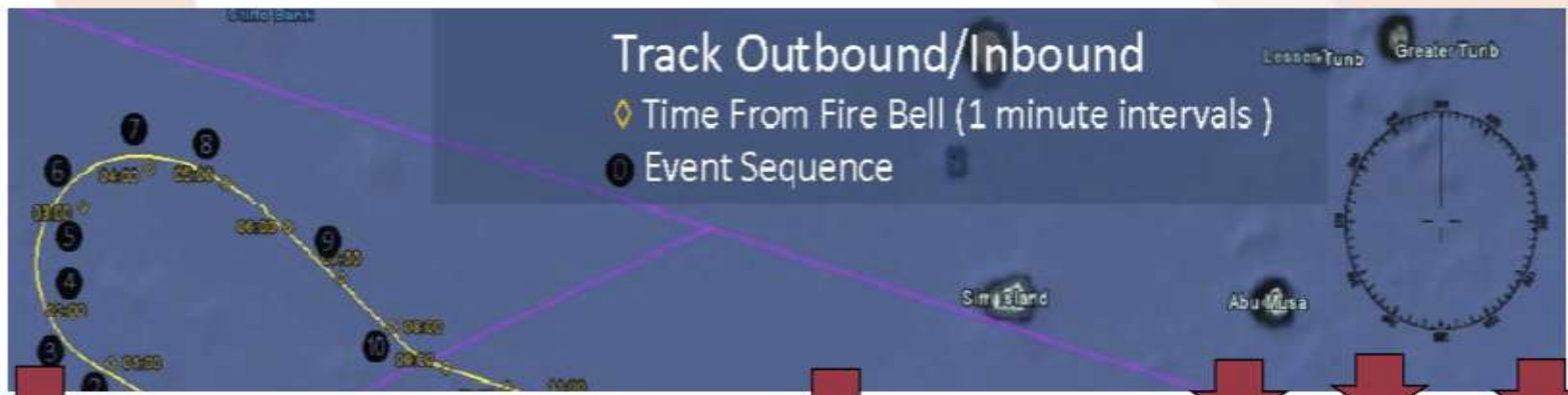
- ▶ Safer
 - ▶ Cheaper
 - ▶ Smaller
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Track Outbound/Inbound

◆ Time From Fire Bell (1 minute intervals)

① Event Sequence





Item No.	Position	Item Description	Battery Type?	Cell or Battery Pack?	Voltage	Watt-hour rating	Amp-hour rating	Equivalent lithium content	UN Test Report? (Y/N)	Battery Meets UN Standards?	MSDS? (Y/N)
8	6R	LiFePO4 batteries for electric vehicle	Lithium ion	Battery Packs (P/N: 9070260, 7070260, 70173248)	48V, 36V, 24V	1056Wh, 972Wh, 480Wh	22Ah, 27Ah, 20Ah	6.6g, 8.1g, 6.0g	N	?	Y (MSDS does not match P/N)
13	10R	LiFePO4 batteries for electric vehicle	Lithium Ion	Battery Packs (P/N: 9070260)	48V	1056Wh	22Ah	6.6g	N	?	Y (MSDS does not match P/N)
15	18R	laptop battery sample	Lithium ion	Battery Packs (P/N: 213282-001)	14.8 V	33 Wh	2.2Ah	0.66g	N	N	Y (Inconsistencies noted)
				Battery Pack							Y