CTA計画で導入されるFlywheelを用いた大電力供給装置の開発状況

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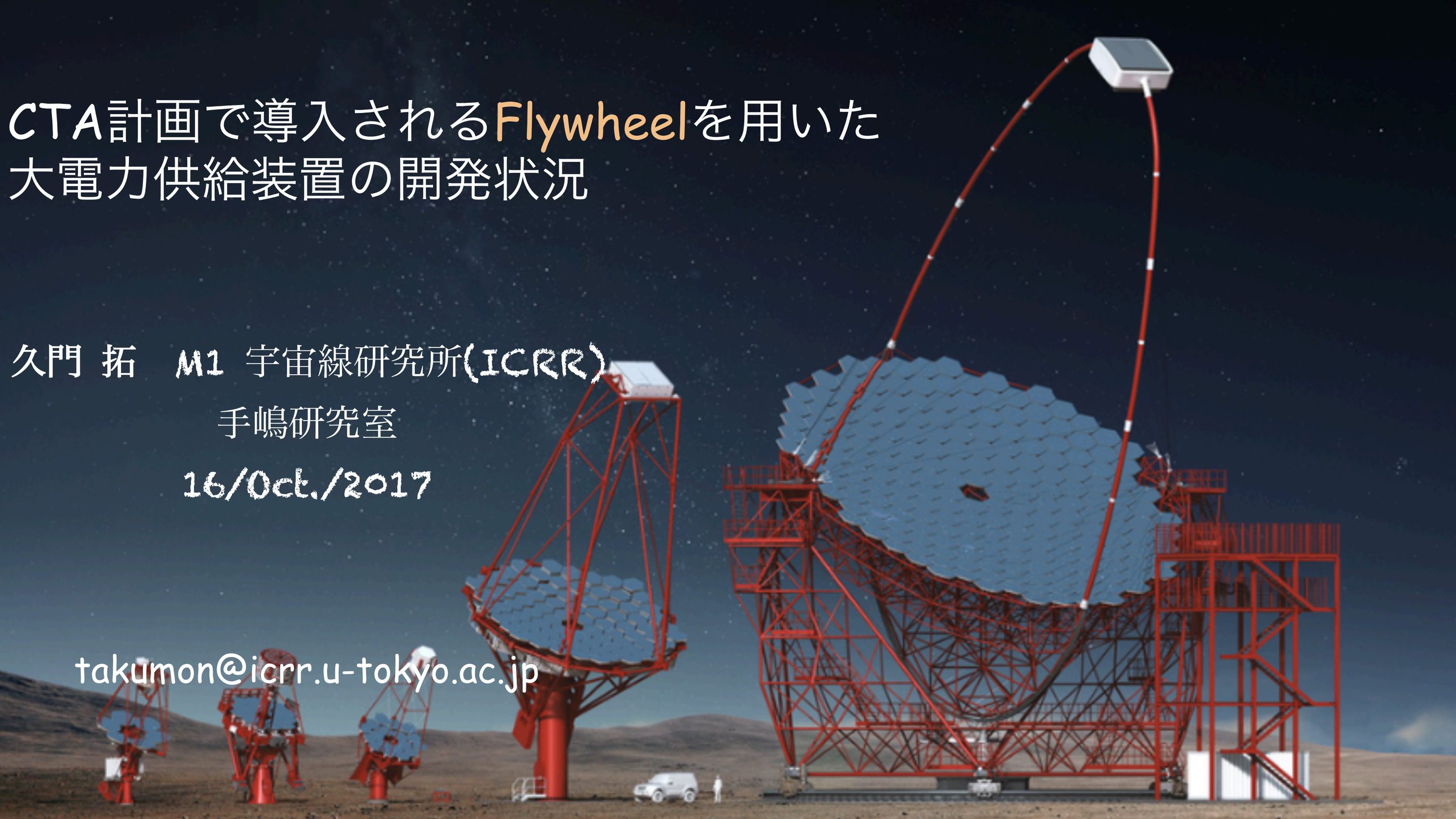
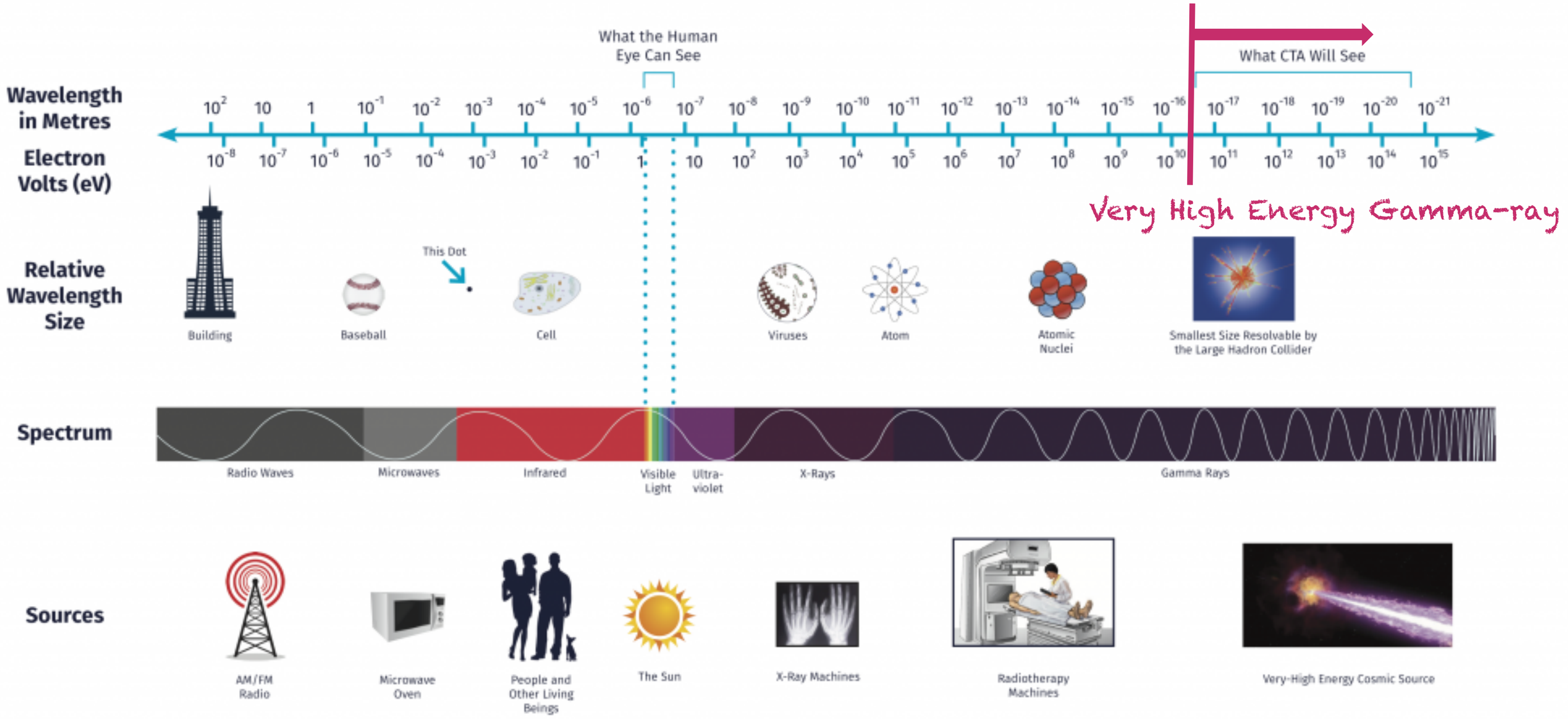


Topic

- ✓High energy gamma-ray astrophysics
- ✓Gamma ray burst (GRB)
- ✓Cherenkov Telescope Array (CTA)
- ✓UPS & Flywheel
- ✓Flywheel Performance Test @Switzerland

Introduction

High Energy Gamma-ray astrophysics



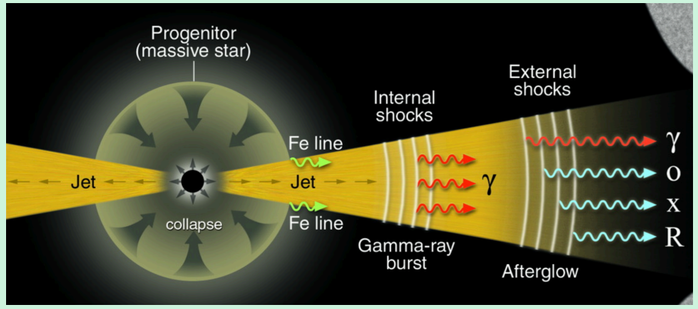
High Energy Gamma-ray astrophysics

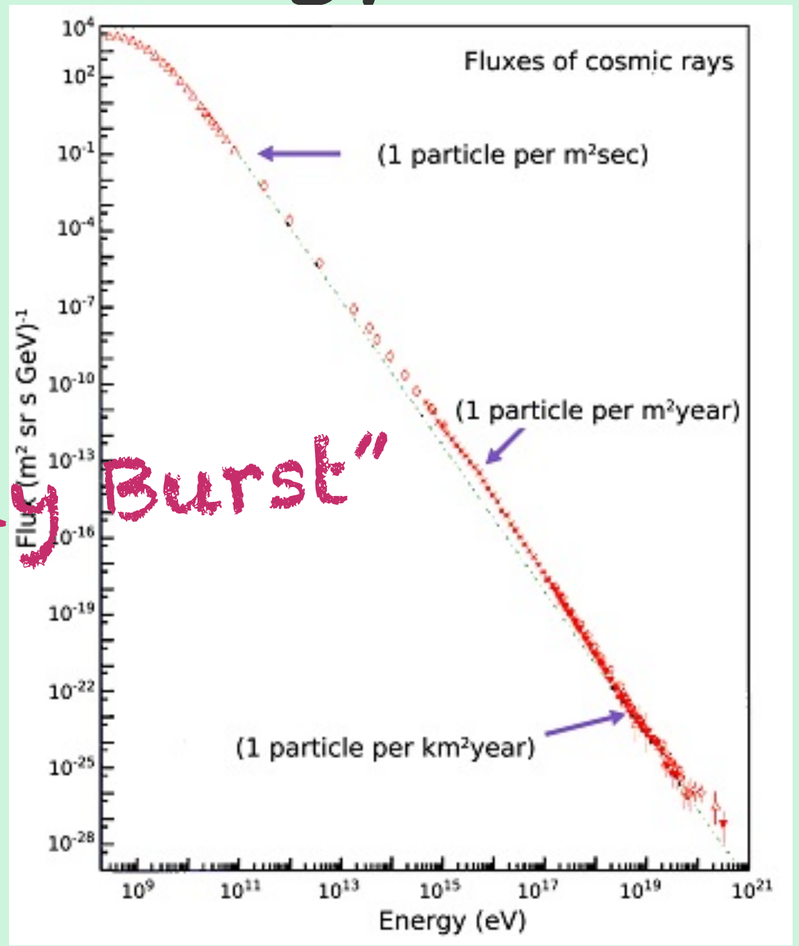
- Astrophysics in developing energy field

Fewer event rate, but...

- Dynamic phenomena
- Explosive phenomena

Transient -> "Gamma ray Burst"





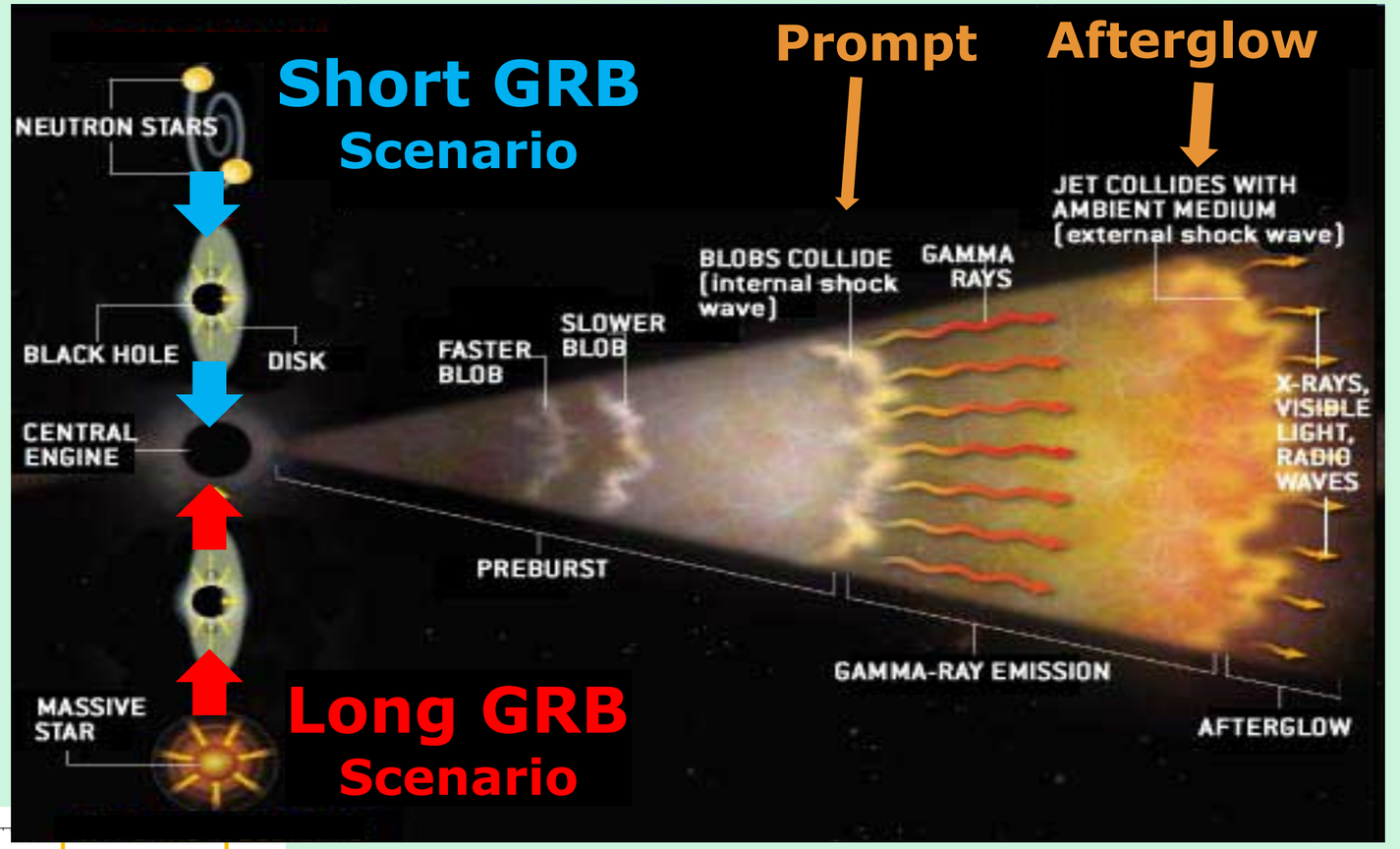
Gamma Ray Burst

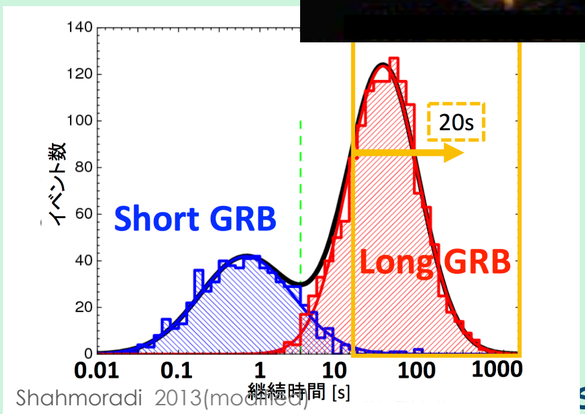
Gamma Ray Burst (GRB)

- GRB

strongest

  - Luminosity ~ 10^{51} erg/s
  - Γ = 100~1000
  - Jet structure
  - Prompt emission & Afterglow
    - Short : merger
    - Long : collapsar



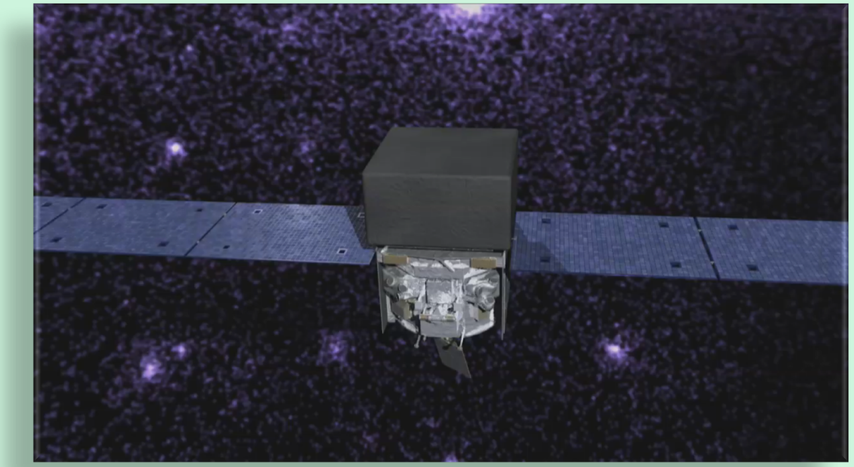


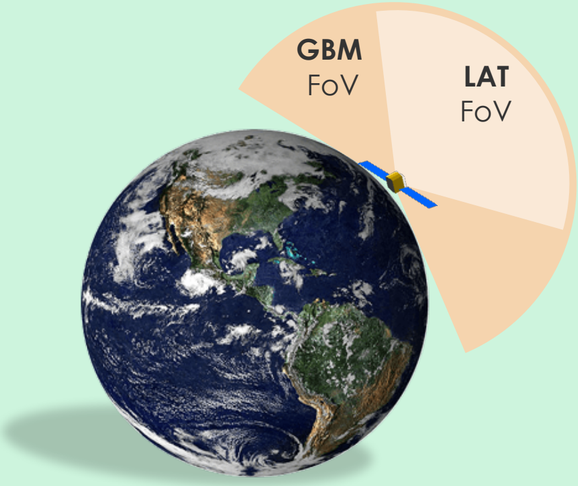
Shahmoradi 2013(modified)

Gamma-ray Telescopes

Fermi Gamma-ray Space Telescope

- **Fermi** since 2008
  - In the space
  - LAT (Large Area Telescope)
    - 20MeV to 300GeV
  - GBM (Gamma-ray Burst Monitor)
    - 8keV to 30MeV



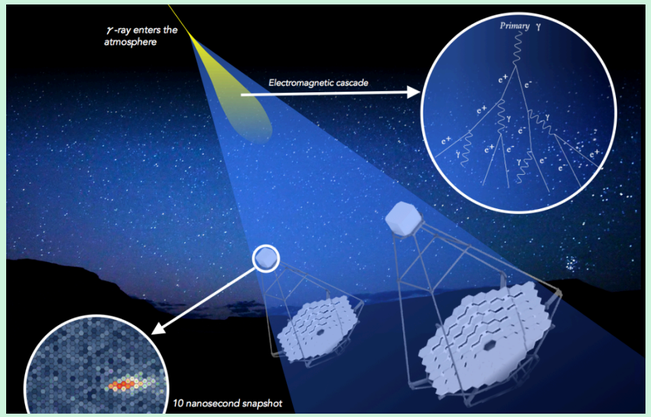


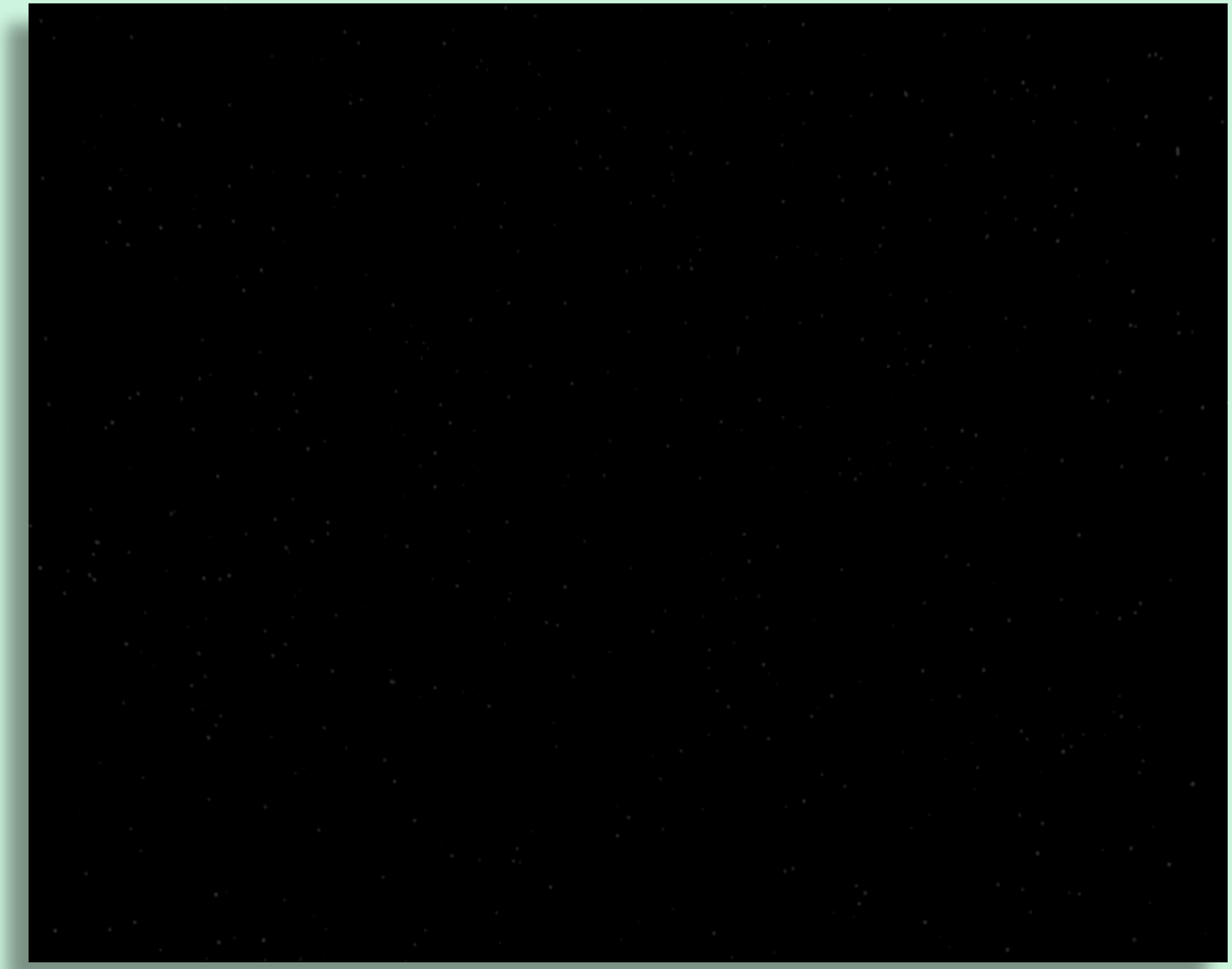
Small GBR statistics above GeV

Imaging Atmospheric Cherenkov Telescope (IACT)

- IACT
  - On the ground
  - Using Cherenkov light
  - Larger detection area

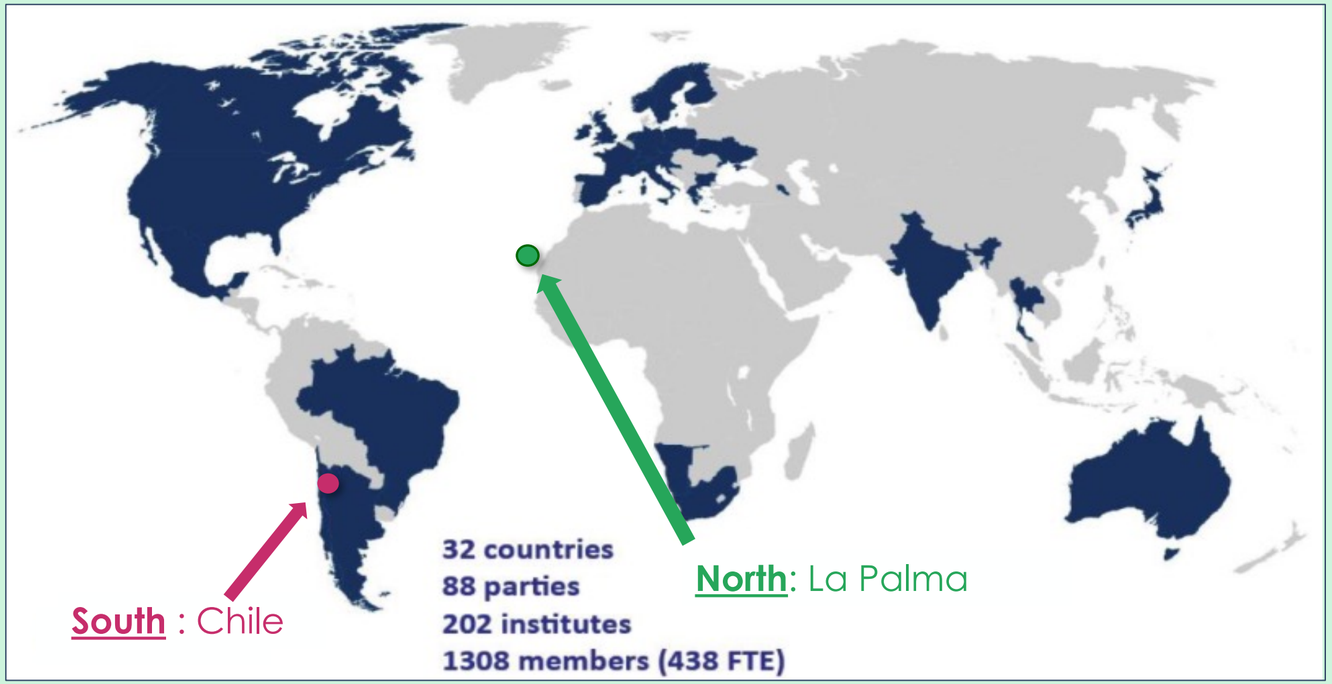
Never detect GRB





Cherenkov Telescope Array (CTA)

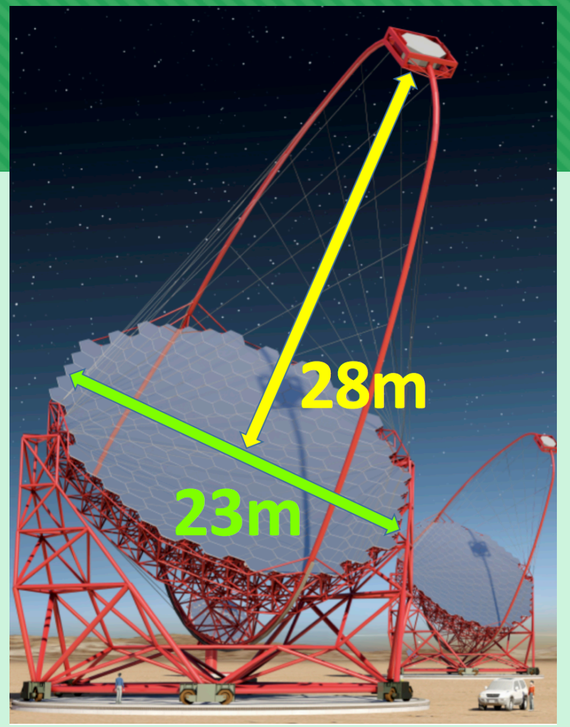
- CTA
  - The next generation of IACT
  - 32 countries
  - 2 sites (North/South)
  - First light: 2018 (North)
  - LST, MST, SST

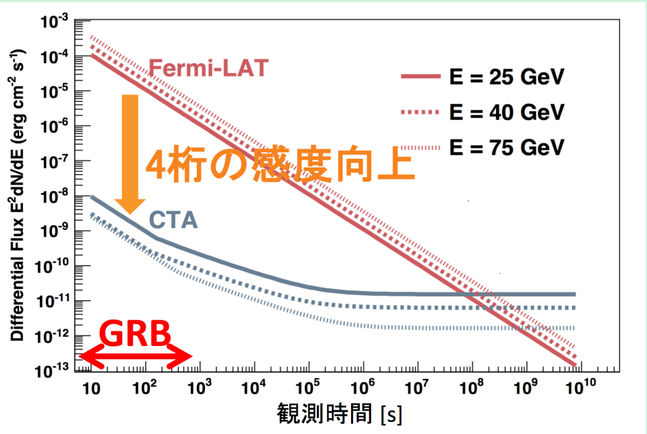


Large size telescope (LST)

- LST 20GeV to 1TeV gamma-ray
  - 23m diameter (paraboloid)
  - Field of View = 4.5°
  - Threshold > 20GeV
  - ×10,000 more sensitive than Fermi in GRB

-> Aim for first detection of GRB on the ground

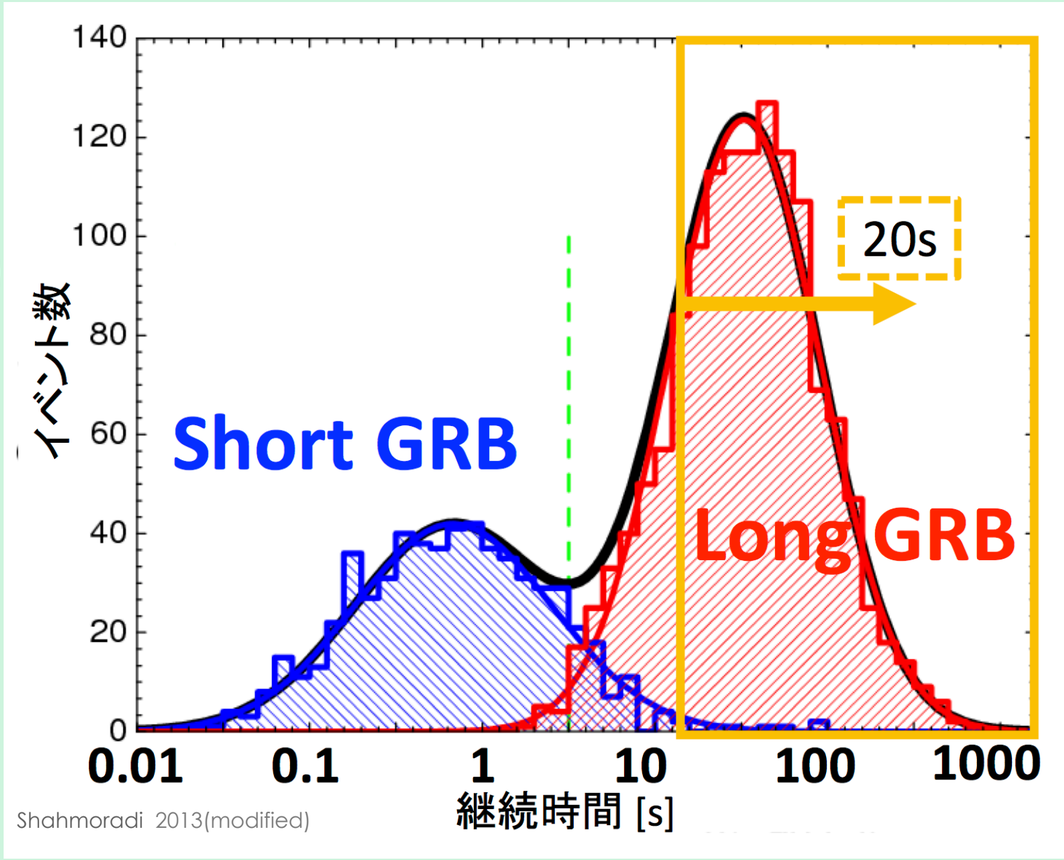




Detect GRB on the ground for the first time

- Requirement to detect **Long GRB**
  - Point to any direction just after LST gets GRB alerts from satellites (Fermi-GBM etc)
  - Within 20 seconds !!

Peak energy supply system

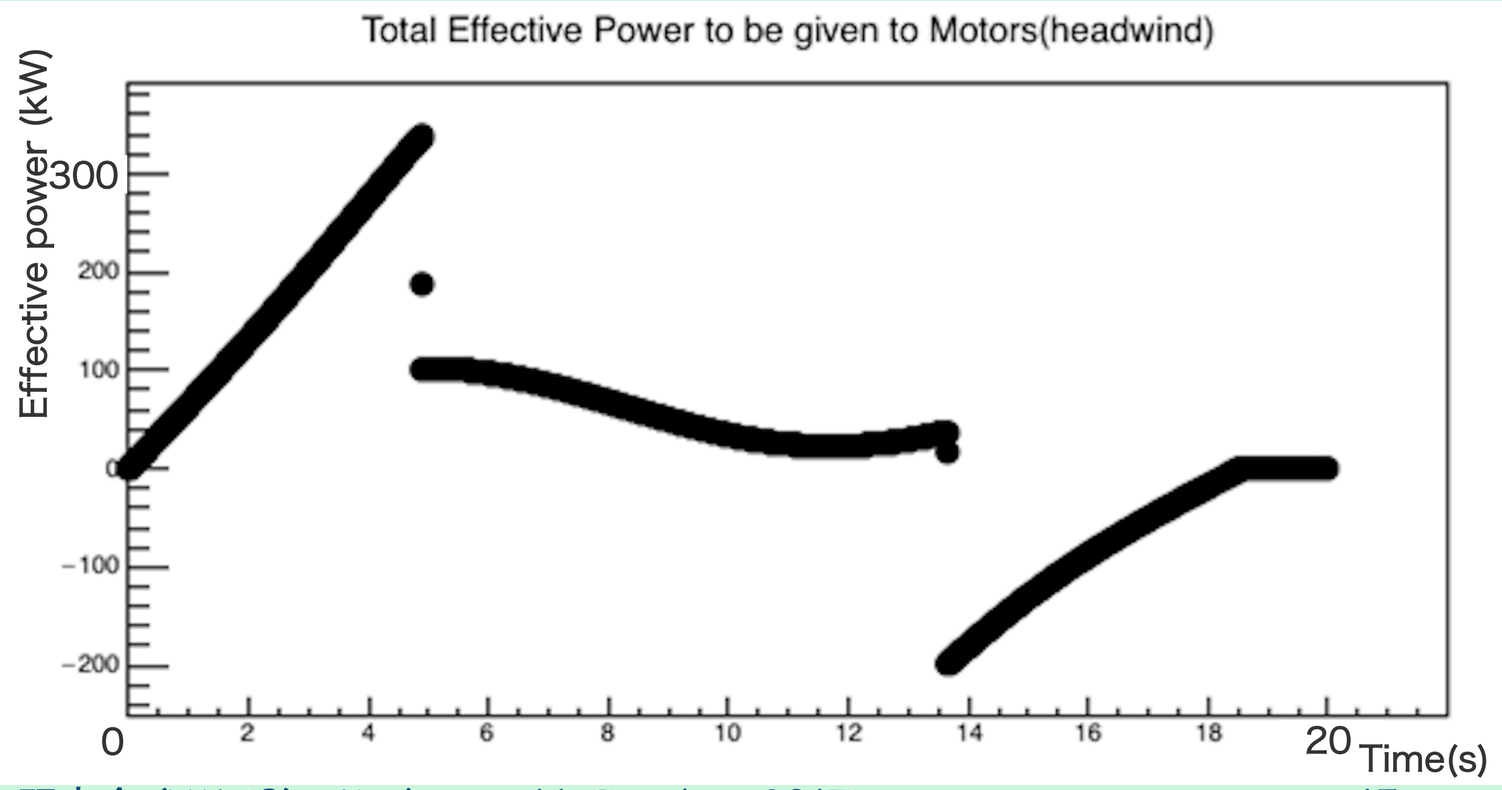


Peak energy supply
UPS & Flywheel

Fast Rotation for GRB

- Power required for 20s pointing
  - In the worst case (60km/s headwind)
  - Peak energy: 350kW

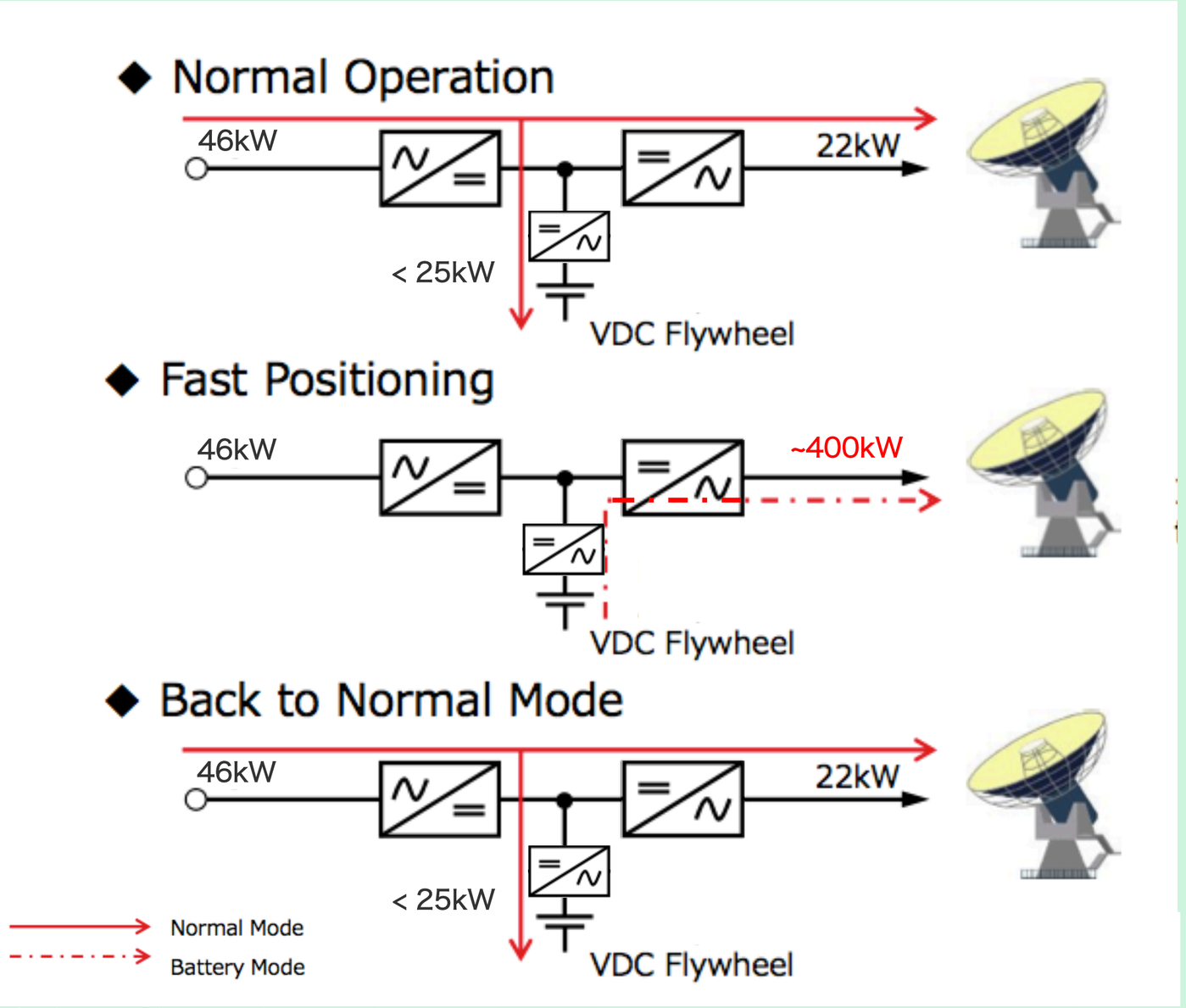
Very High



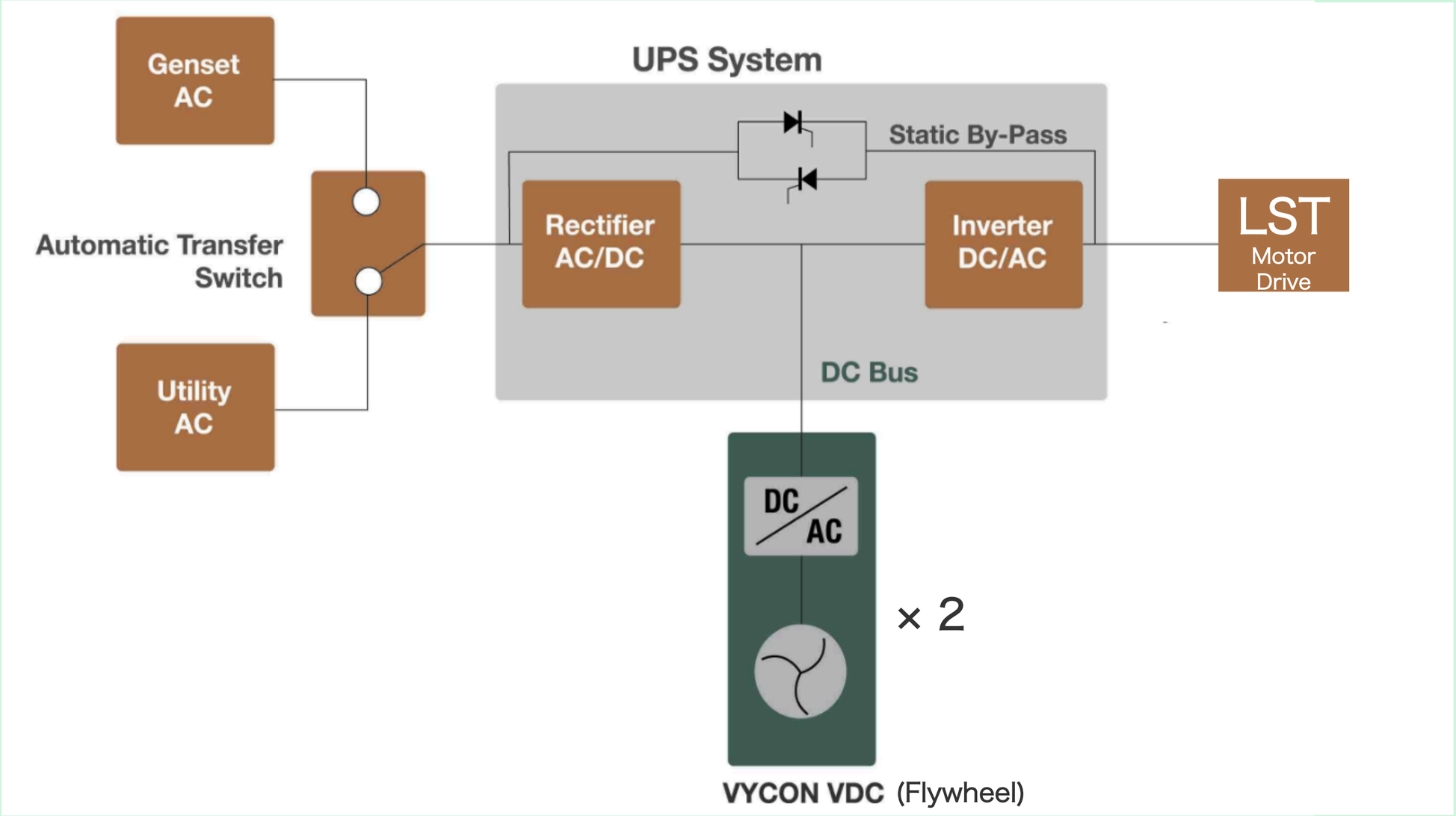
Peak energy supply system

- UPS
- Flywheel

- Normal mode
  - Charge up with weak current
- Fast Rotation mode
  - After GRB alert comes
  - Huge current flows

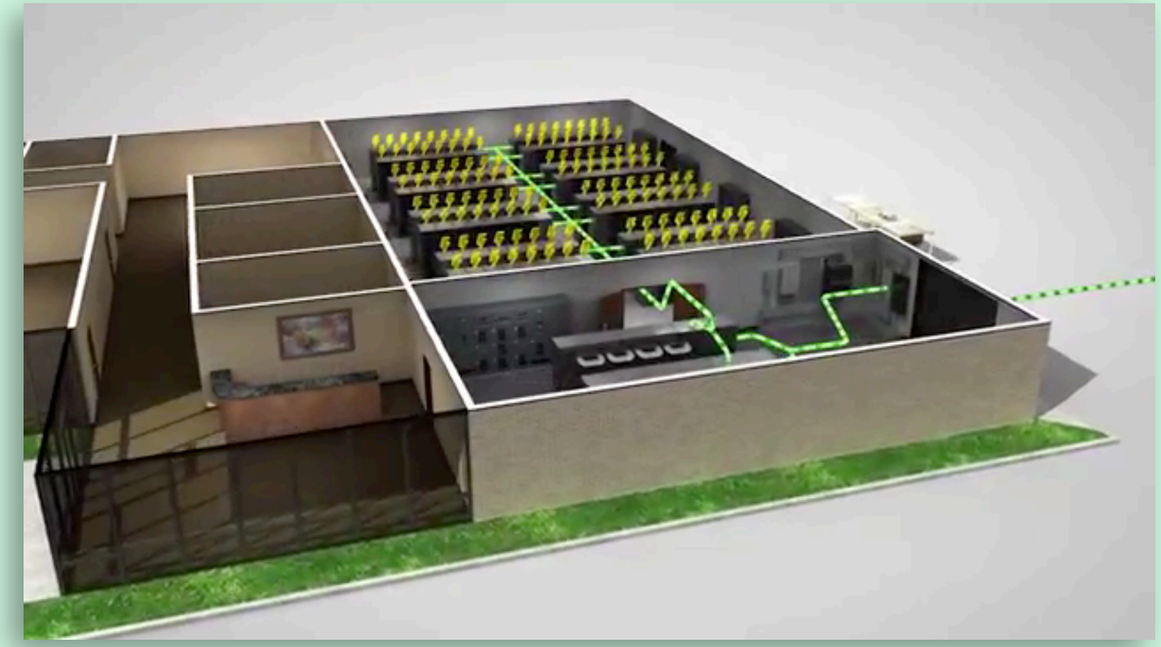


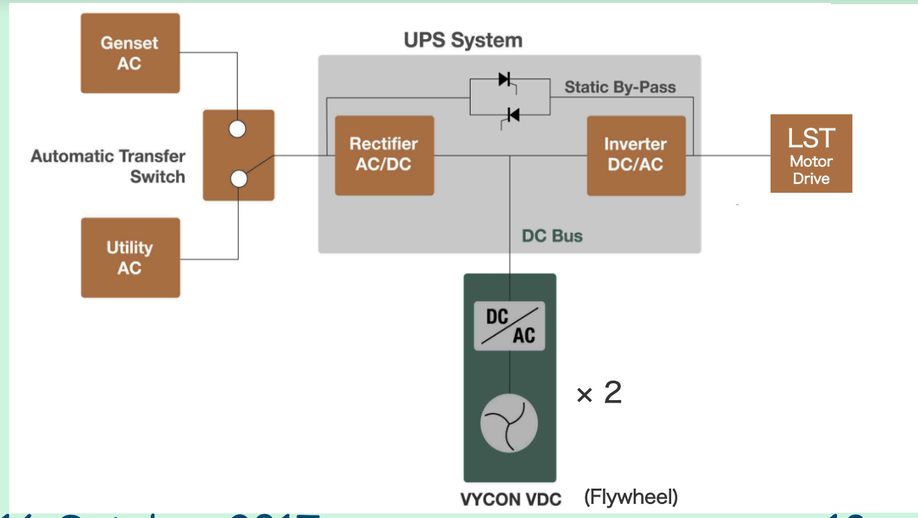
UPS & Flywheel for 1 LST



Uninterruptible Power System (UPS)

- UPS (TLE 600kVA)
  - In interruption of electric service….
    1. Power is transferred from Batteries <- Flywheel
    2. Switch is changed automatically to diesel generator
  - Constant Voltage & Frequency

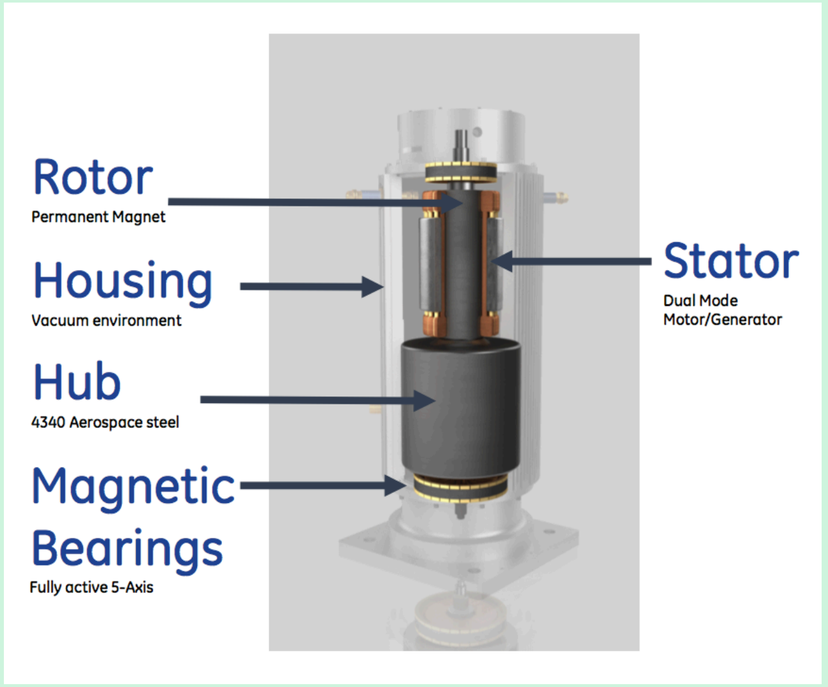




Flywheel

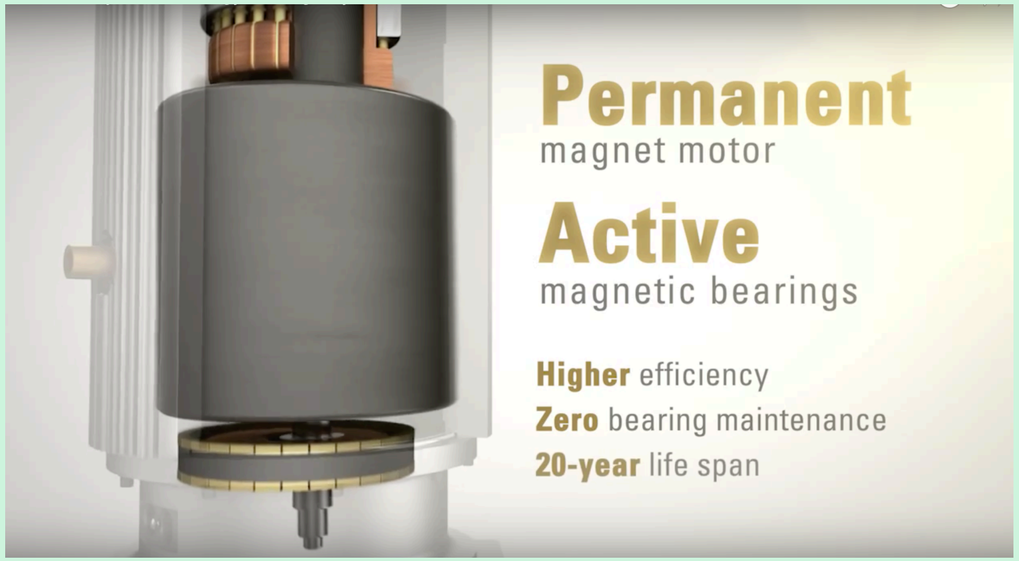
- Flywheel (VDC XE)
  - Energy is stored as "Rotational energy"
  - Vacuum & Magnetic levitation
  - 99.4% efficient
  - 20 year life

Mechanical Battery



Advantage of flywheel

- Comparing with chemical battery
  - Smaller footprint
  - No hazardous materials
  - Higher efficiency
  - Fewer maintenance
  - Longer life



20-year life is the same as CTA Operation period

Flywheel installation in CTA

- No Flywheel is installed on telescopes ever

  This is the first project in the world !!!

- This installation will be useful for
  - Remote location
  - Cases required long life time & huge power ocasionally

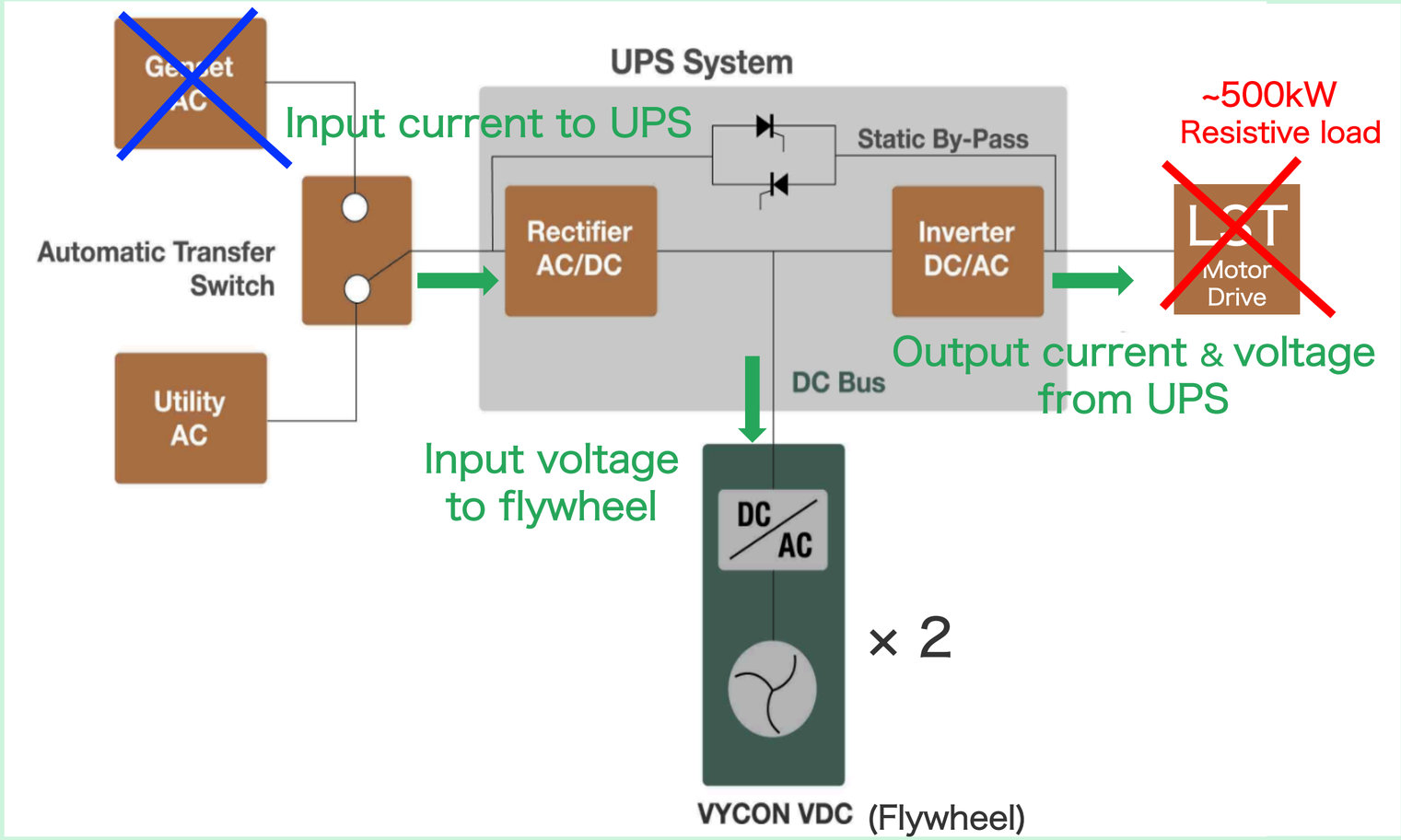
Flywheel Performance Test

September / 2017 Riazzino, Switzerland

Set up

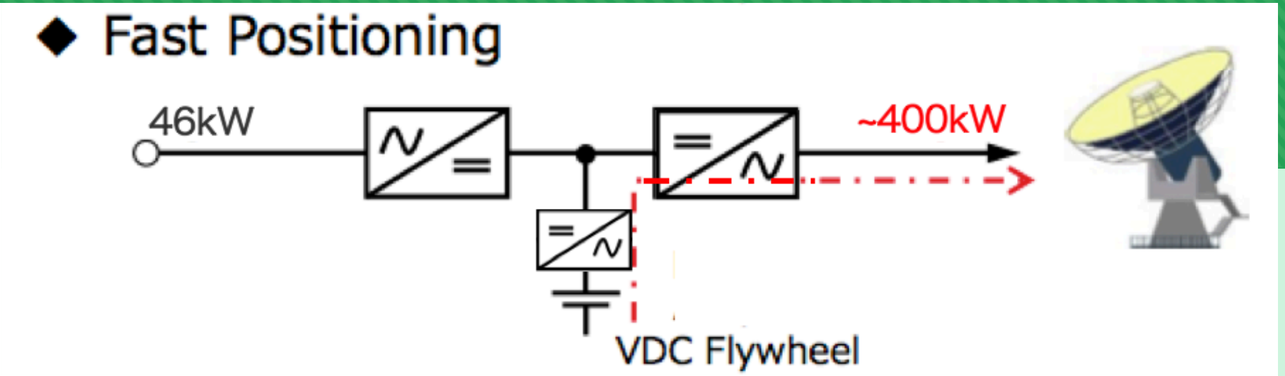
- ✓ Steady state load: 22kW
- ✓ Rectifier limited: 46kW

- 5 case studies



case 1
Realistic GRB case

1. Realistic case



- Realistic case of GRB
  - ✓ Discharge for 10 seconds
  - ✓ Measure the level of charge of the flywheels at the end of the 10 seconds
  - ✓ Measure the time to fully recharge the flywheels at 100% capability
- Result
  - ➢ Flywheels level of charge: 100% -> 40%
  - ➢ Time to fully recharge the flywheels (40% -> 100%) : about 15 minutes

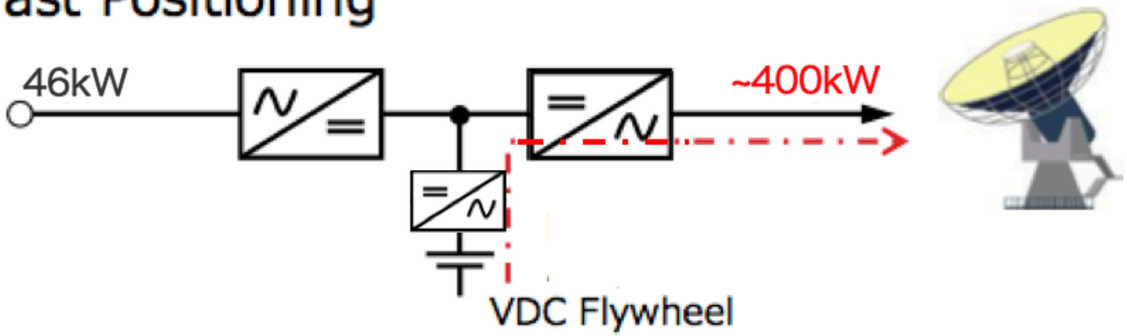
1. Realistic case

- Input/ Output power
  - Input: 65.7A × 400V × $\sqrt{3}$ = 45.5kW
  - Output: 688.8 A× 400V × $\sqrt{3}$ = 477kW

-> UPS & Flywheel can transfer enough power for GRB

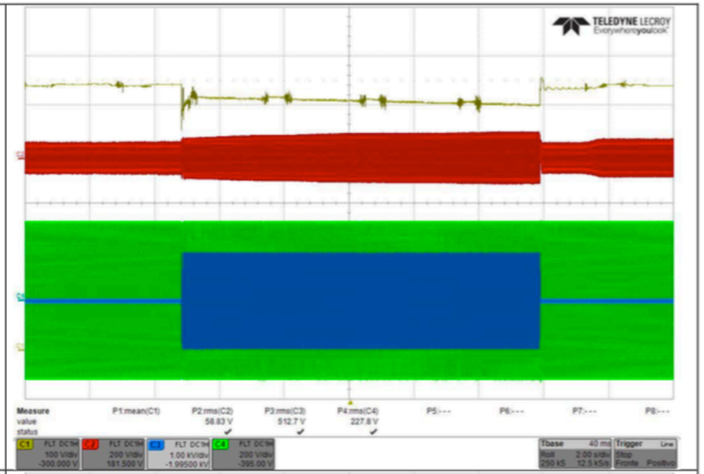
-> Flywheels can leave 40% of the energy storage after fast rotation

◆ Fast Positioning



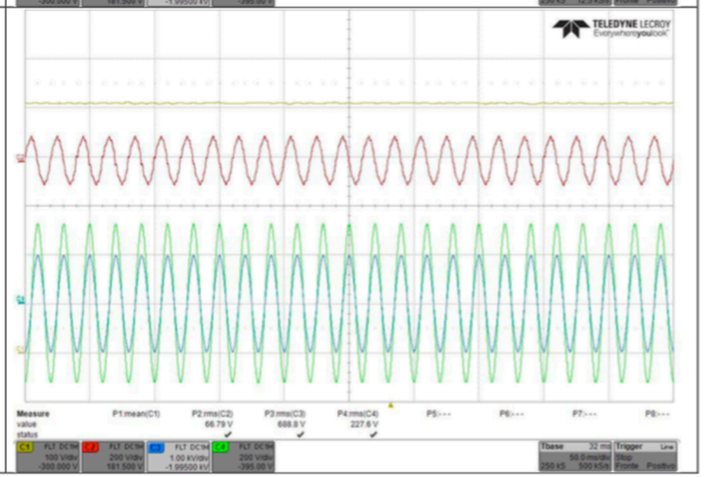
Result:

Ch	1	UDC	=	100	V/ Div
Ch	2	Iinput	=	200	A/ Div
Ch	3	Iout	=	~~500~~ 1000	A/ Div
Ch	4	Vout	=	~~500~~ 200	V/ Div



Ch	1	UDC	=	100	V/ Div
Ch	2	Iinput	=	200	A/ Div
Ch	3	Iout	=	~~500~~ 1000	A/ Div
Ch	4	Vout	=	~~500~~ 200	V/ Div

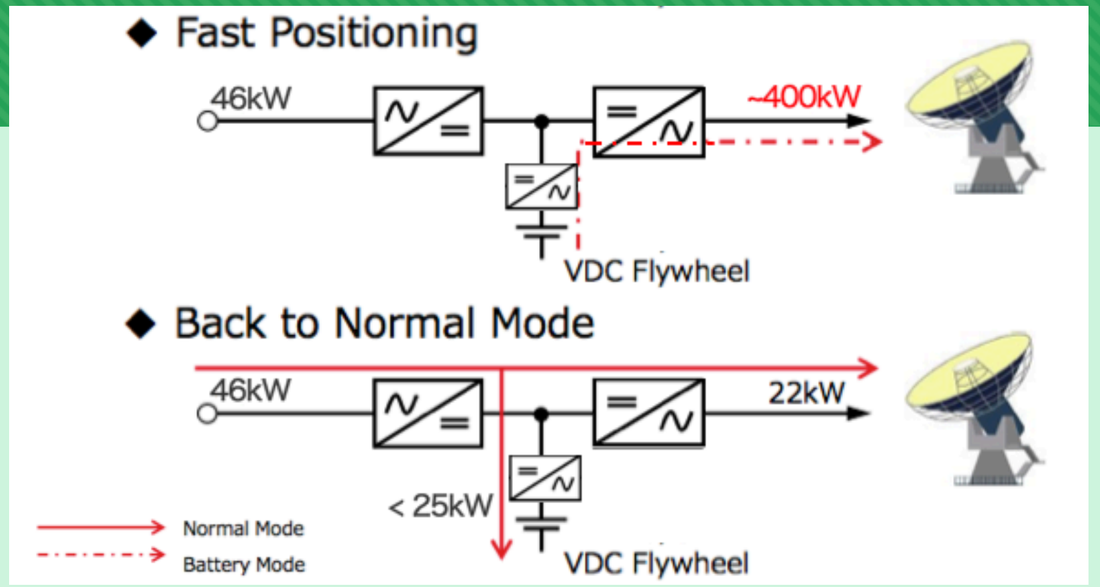
Expansion of the above picture



case 2
Fully discharged case

2. Fully discharged case

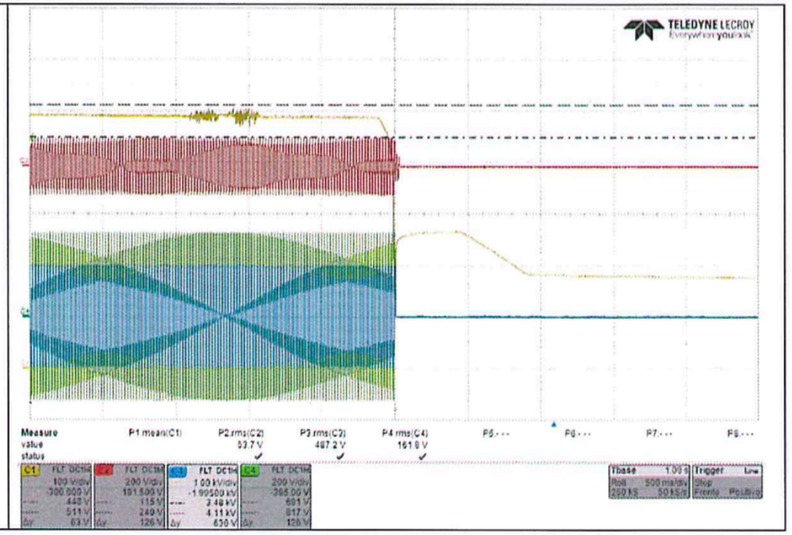
- Flywheels transfer all energy
  - ✓ Measure the time to fully discharge & fully recharge
- Result
  - ➢ Time (100 %-> 0%) : 18 seconds
  - ➢ Time (0% -> 100%) : 28 minutes



Then, breaker dropped

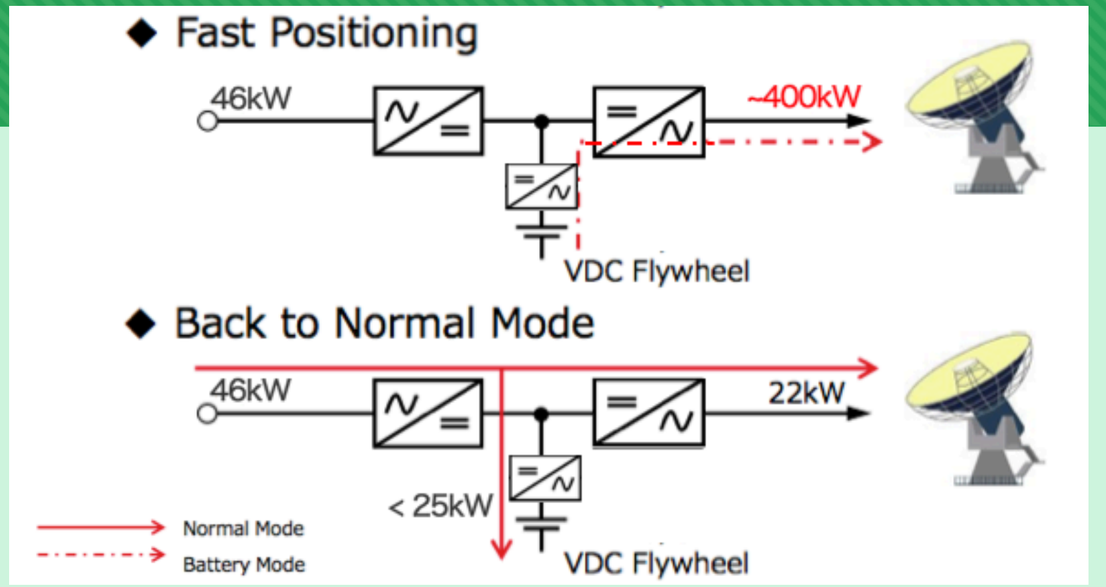
Result

Ch	1	UDC	=	100	V/ Div
Ch	2	Iinput	=	200	A/ Div
Ch	3	Iout	=	500	A/ Div
Ch	4	Vout	=	500	V/ Div



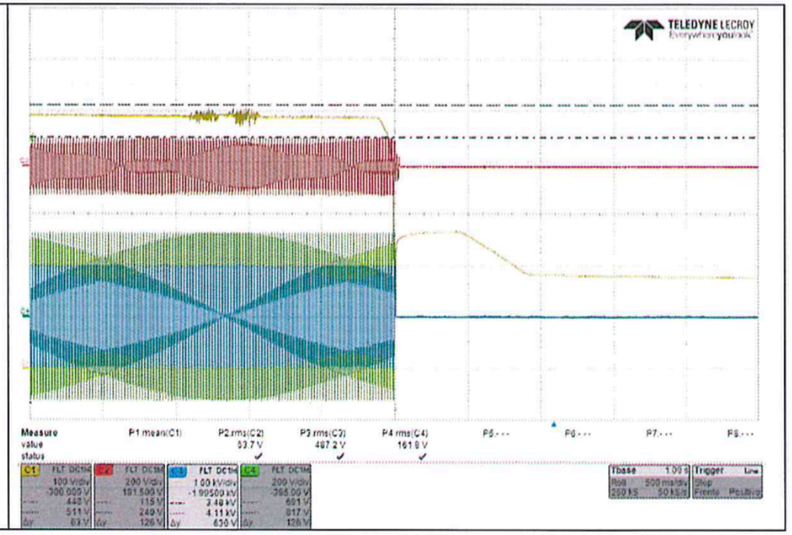
2. Fully discharged case

- Problem
  - To recover the system, we have to raising the breaker by hand
- We try NOT to drop breaker



Result

Ch	1	UDC	=	100	V/ Div
Ch	2	Iinput	=	200	A/ Div
Ch	3	Iout	=	500	A/ Div
Ch	4	Vout	=	500	V/ Div

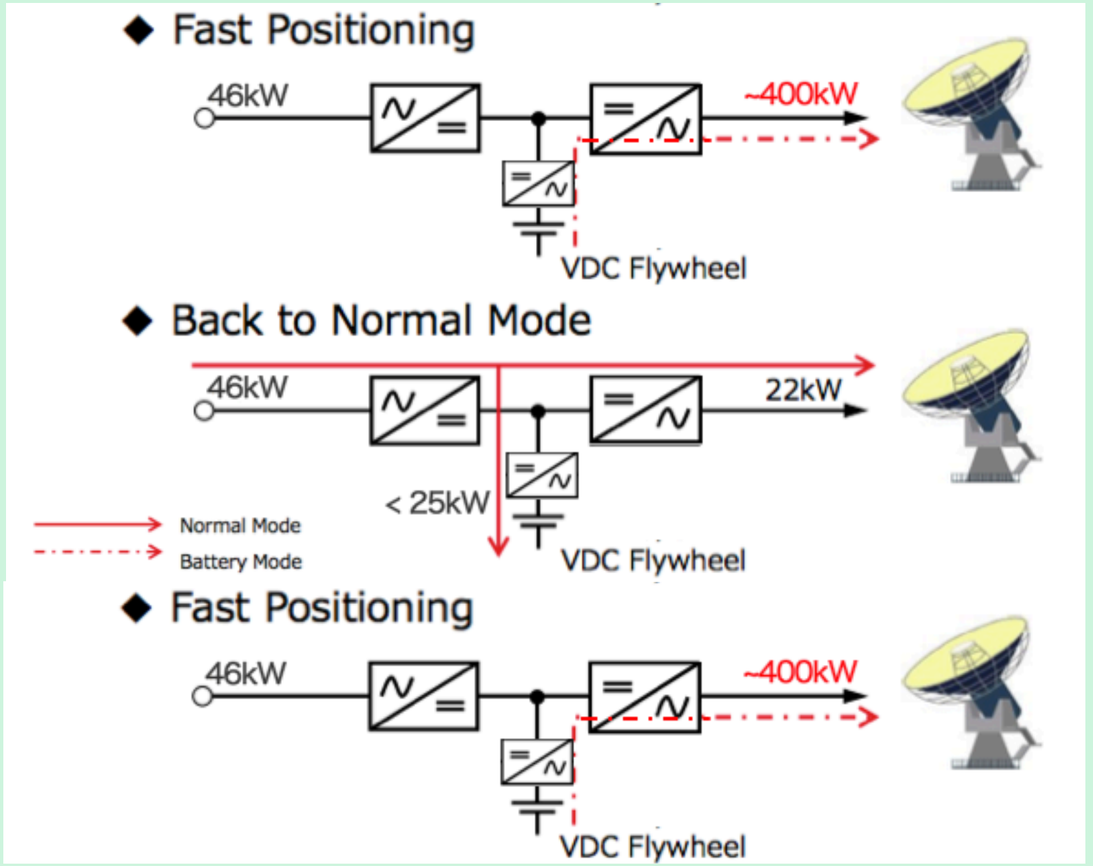


Case 3.
Another GRB some min. after one GRB

3. Another GRB some min. after one GRB

- Two GRBs occurs almost at the same time
  - ✓ Discharge for 10 seconds
  - ✓ Let flywheels charge for 5 minutes
  - ✓ Discharge for 10 seconds again
- Result
  - ➢ First discharge: 100% -> 40%
  - ➢ 5-minute charge: 40% -> 62%
  - ➢ Second discharge: 62% -> 7%

Left

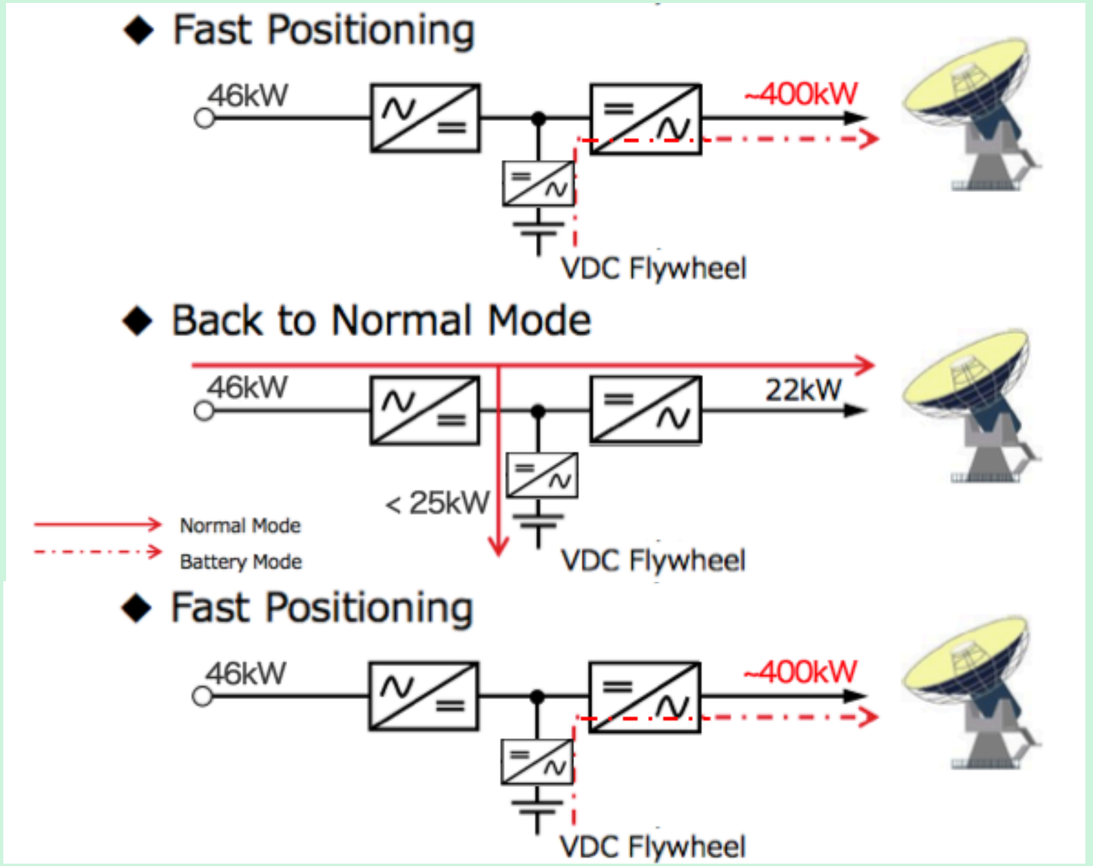


3. Another GRB some min. after one GRB

- Two GRBs occurs almost at the same time

-> Enable to detect another GRB which happens after some minutes

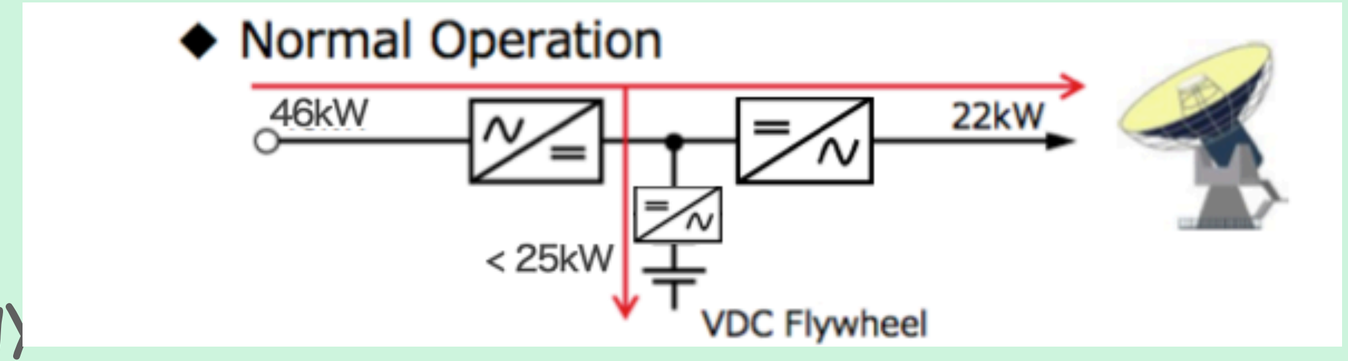
-> The minimum energy percentage of fast rotation mode should be determined



case 4
Input power shortage

4. Input power shortage

- Case that input power is not enough
  - ✓ Rectifier limited: ~~46kW~~ -> 26kW
- Result
  - ➢ Charging: Failure -> loss energy
  - ➢ But UPS & Flywheels don't tell their situations

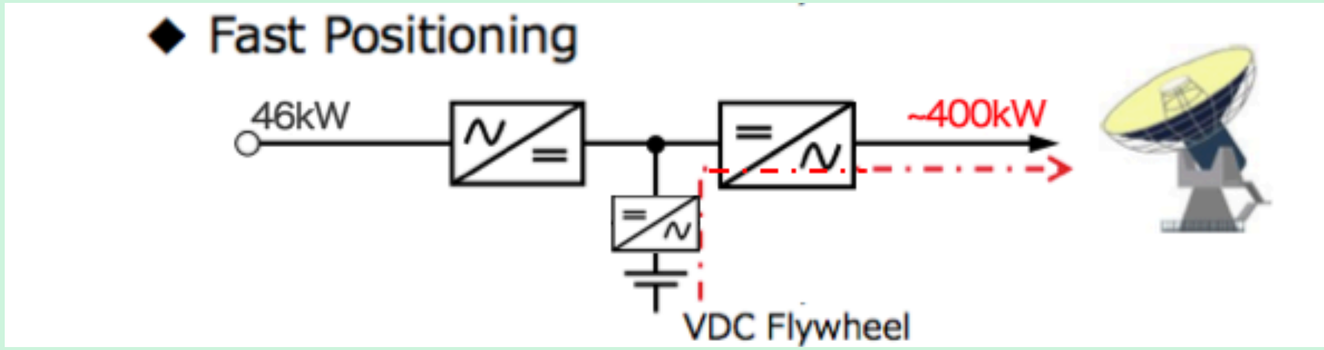


➢ Alerts of charging failure is required

case 5
One of Flywheels gets broken

5. One of Flywheels gets broken

- Use the only one flywheel left
  - ✓ Load: ~~500kW~~ -> 200kW
  - ✓ Measure the time to fully discharge



- Result
  - ➢ Flywheels take about 18 seconds to fully discharge

➢ "Semi-fast" rotation with one flywheel can be executed

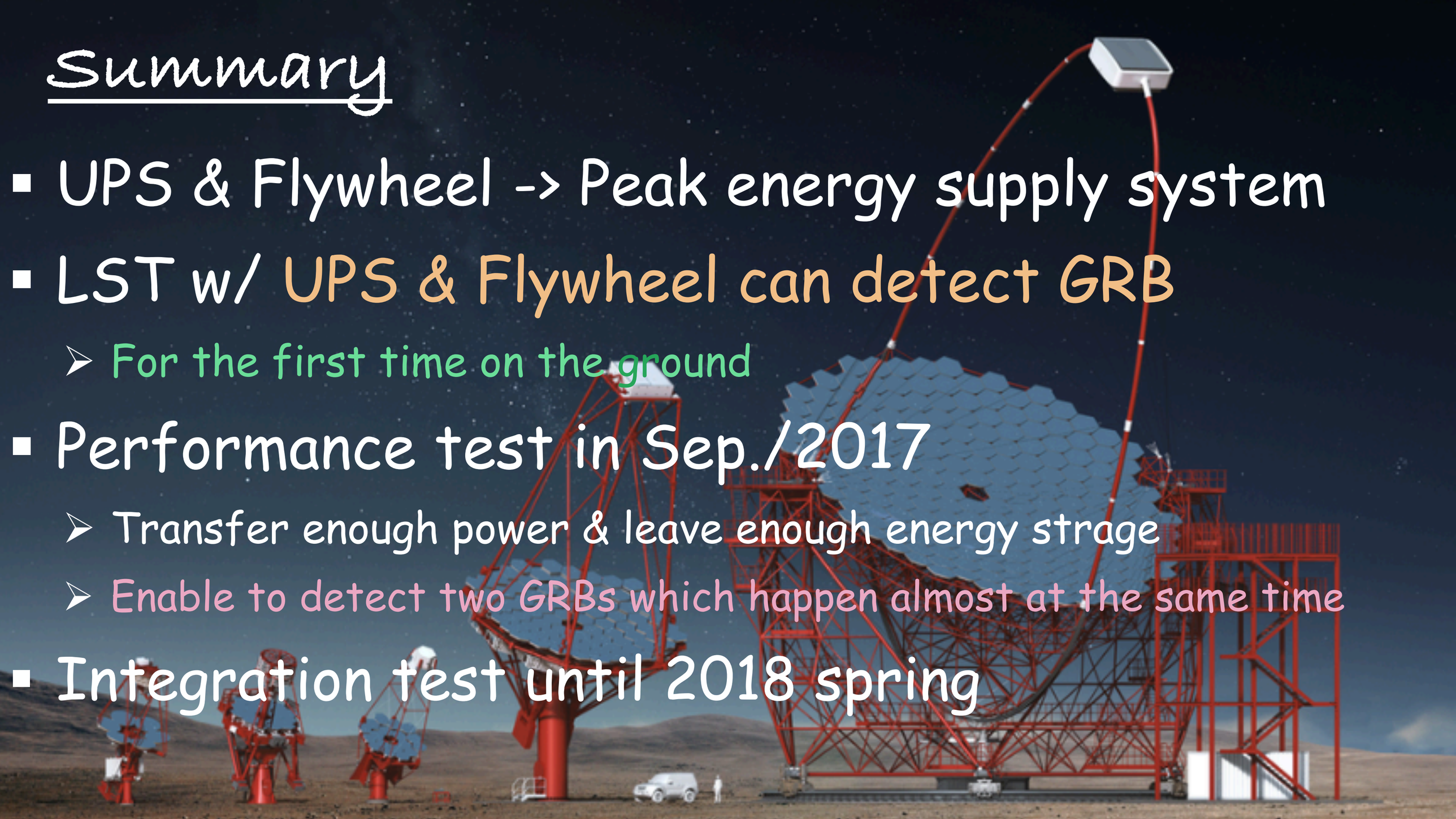
Plan

Plan

- ✓UPS & Flywheels are being shipped to La Palma
- ✓Integration Test w/ Motor Drive System will be done until 2018 Spring
- ✓2018 First Light

Summary

- UPS & Flywheel -> Peak energy supply system
- LST w/ UPS & Flywheel can detect GRB
  - For the first time on the ground
- Performance test in Sep./2017
  - Transfer enough power & leave enough energy strage
  - Enable to detect two GRBs which happen almost at the same time
- Integration test until 2018 spring



Thank you !