Communication Satellite

Satcom ABC series (2)

WU Boyang
APMT

Introduction

Payload

Antenna

Transponder (LNA, D/C, IMUX, LCTWTA and OMUX)

Bus

TC&R Subsystem

Electrical Power Subsystem

Attitude Control Subsystem

Thermal Control Subsystem

Propulsion Subsystem

Satellite and Its Subsystems

CHINA APMT

- COMMUNICATION SATELLITE
  - BUS (PLATFORM)卫星平台
    - Telemetry & Command 遥测遥控
    - Electrical Power 电源
    - Attitude Control 姿态控制
    - Thermal Control 温度控制
    - Propulsion 推进
  - PAYLOAD 有效载荷
    - Communications 通信

Payload

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- ❖ Antennas
  - ➢ C-band coverage
  - ➢ Ku-band coverage
- ❖ Bent pipe transponders
  - ➢ Receiving and transmission
- ❖ Broadcasting service
  - ➢ TV broadcast
  - ➢ Internet access
  - ➢ Communication network
- ❖ Point to point service
  - ➢ Microwave radio relay technology
    - ⇨ as complements of terrestrial cables

Bus

CHINA APMT

- ❖ Platform
  - ➢ The infrastructure providing locations for payload
- ❖ Telemetry and command subsystem
  - ➢ Communication with ground control station
  - ➢ Supporting tracking and ranging by ground stations
- ❖ Electrical power subsystem
  - ➢ Solar cells converting solar energy into electrical power
  - ➢ Batteries maintaining power during solar eclipse
- ❖ Attitude control subsystem
  - ➢ Keeping spacecraft in right orbit
  - ➢ Pointing antennas in right direction
  - ➢ Pointing solar arrays towards the sun

Bus (cont.)

- Thermal control subsystem
  - Keeping all spacecraft parts within acceptable temperature ranges
- Propulsion subsystem
  - Bring spacecraft to desired orbit
  - As actuator for station keeping

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Antennas Onboard

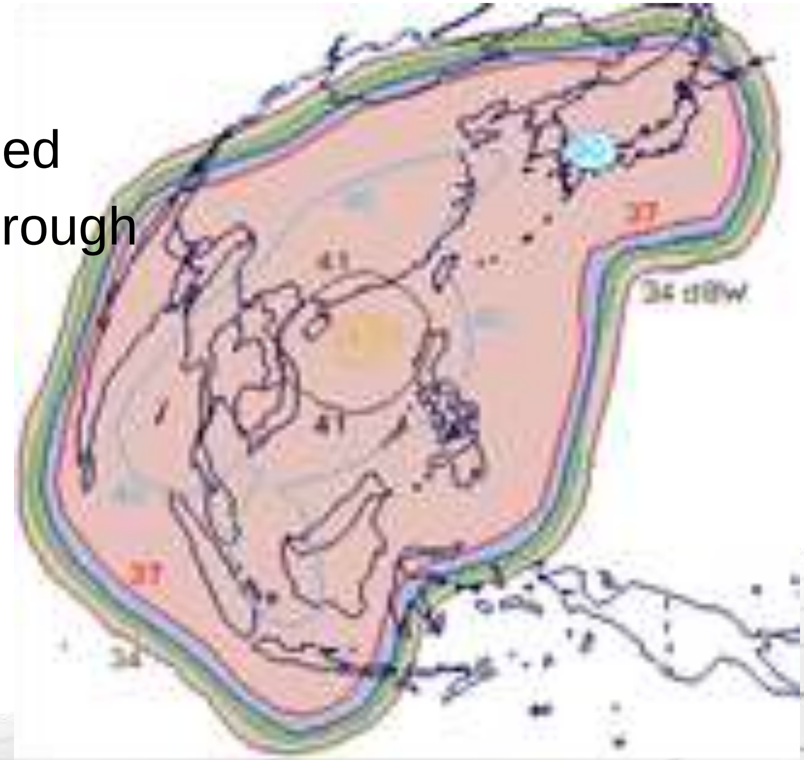
CHINA APMT

- Reflector Antennas
  - Simplest and most effective for FSS and BSS satellite
- Deployable reflector
  - 2 to 3 meters in diameter
  - Mounted on east and/or west side of S/C body
  - Stowed when launch and deployed in-orbit
  - Fine-tuning footprint pointing
- Steerable antenna
  - 1 to 1.5 meters in diameter
  - Mounted on earth deck of S/C body
  - Installed with wider moving range
    - ⇨ antenna pointing could be changed in limited directions

Gain and Coverage

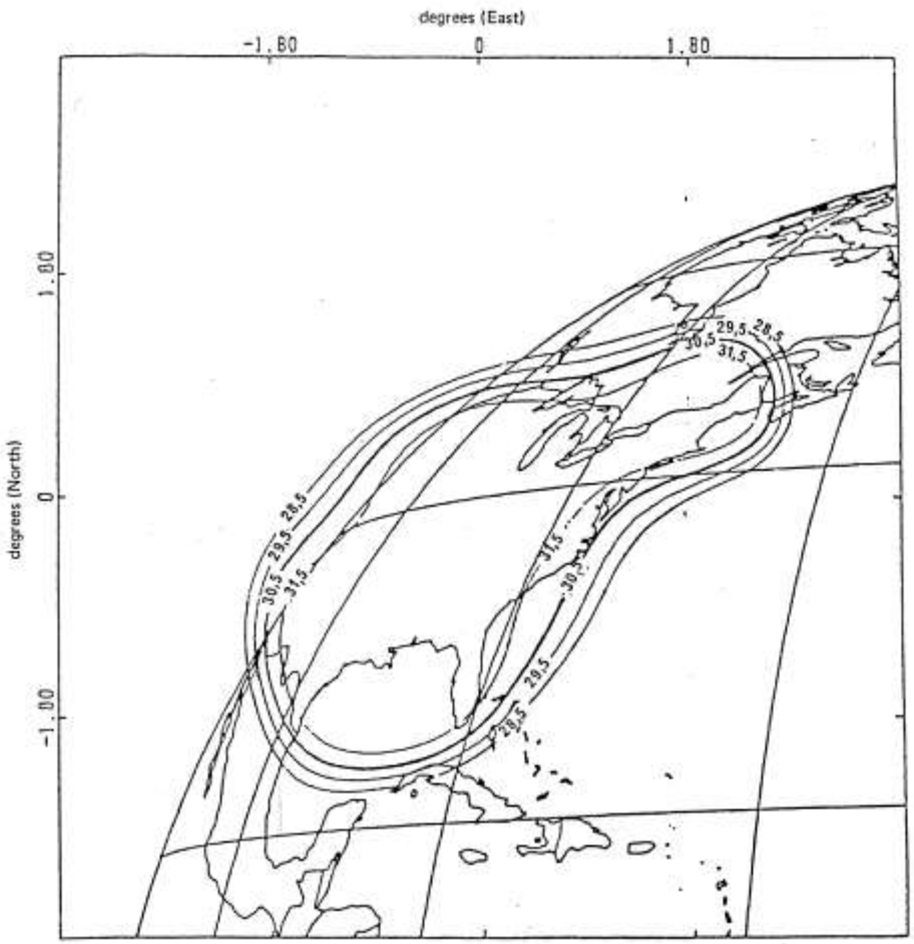
CHINA APMT

- ❖ Antenna gain
  - ➢ Defined as difference in power received by a directional antenna with an isotropic antenna in the same place
    - ⇨ isotropic antenna: radiating same power at all directions
  - ➢ dBi: decibel gain referenced to an isotropic antenna
    - ⇨ gain of isotropic antenna: 0dBi
- ❖ Antenna pattern
  - ➢ A map showing antenna designed specification by contour lines through points of equal antenna gains

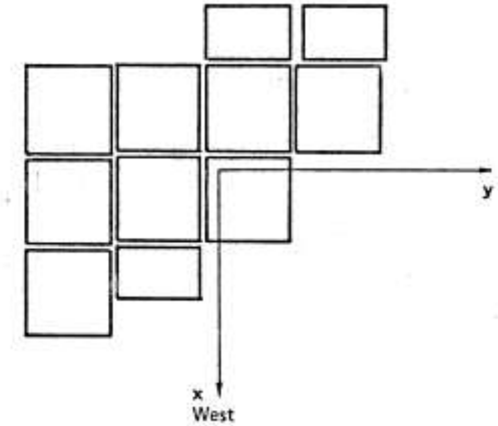


Gain and Coverage (cont.)

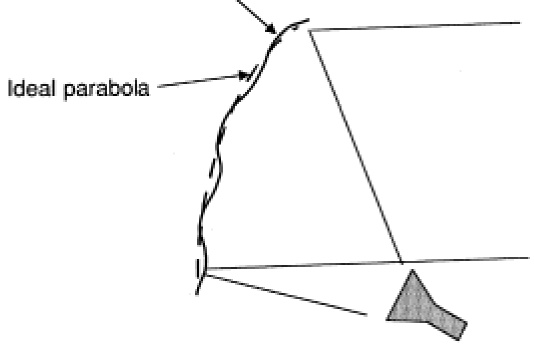
- Antenna pattern (cont.)
  - Achieved by using multiple feeds system or shaped reflector



(a) iso gain contours



(b) Feed geometry



Conceptual drawing, in cross-section, of a shaped offset reflector.

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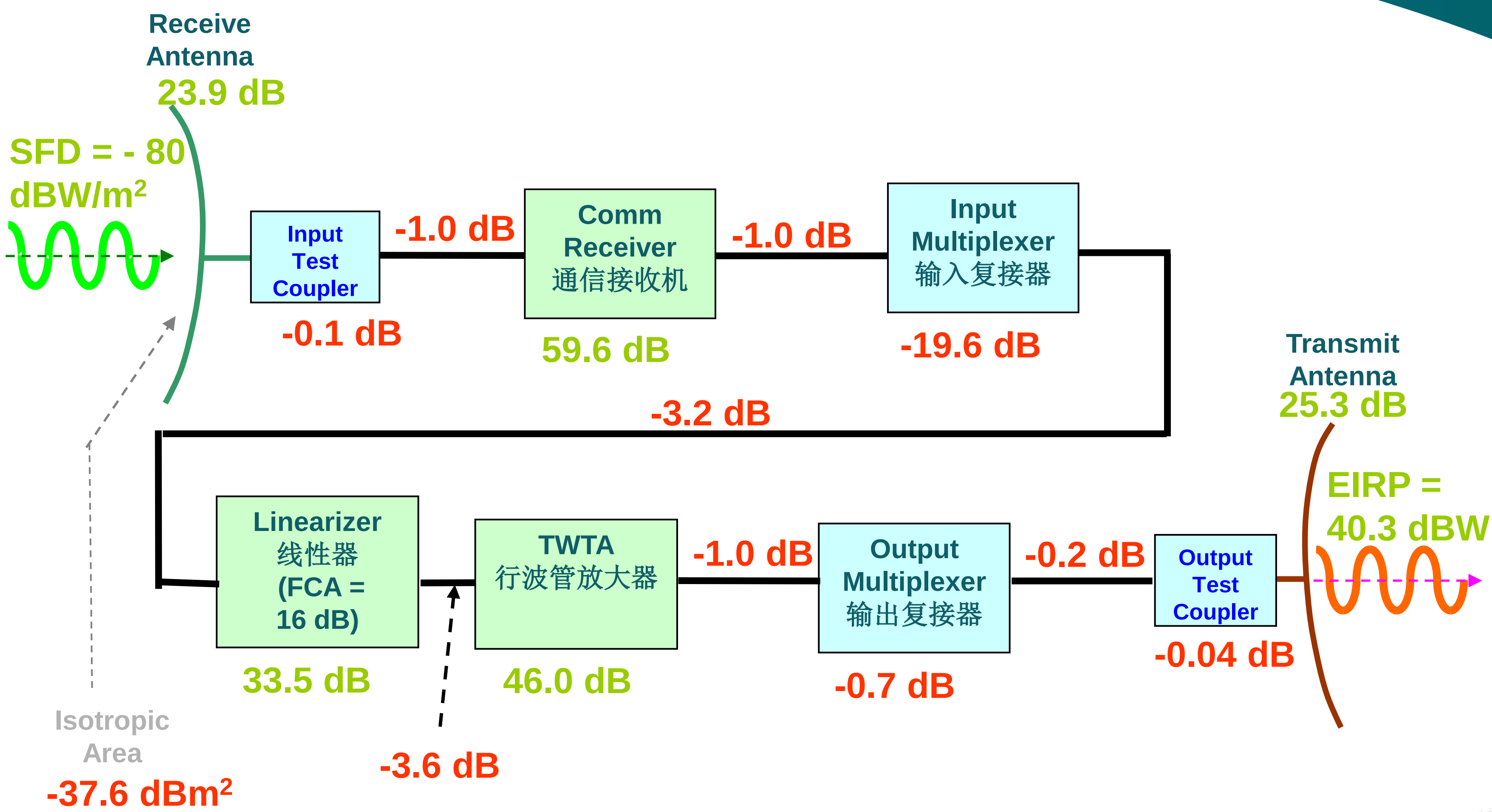
  - **Propulsion Subsystem**

Communication Payload

- Transponder
  - Mainly operating in C-band (6/4 GHz) and Ku-band (14/12 GHz)
- Basic functions
  - Frequency translation
  - Power amplification
  - Noise filtering
- Modules
  - Antenna
  - Wideband receiver
    - LNA and D/C
  - Input and output multiplexer
  - LCTWTA
    - LCAMP (linearizer, FGM/ALC), TWTA
- Redundancy
  - Receiver and LCTWTA

C-band Transponder Gain / Loss Budget



Communication Payload (cont.)

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- Receiver
  - LNA: low noise amplifier
    - Noise figure: < 1.5dB (dominant of the entire system)
  - D/C: down converter
    - C-band: 6 GHz to 4 GHz
    - Ku-band: 14 GHz to 12 GHz
  - 60dB gain: to amplify input signal
- IMUX
  - Input Multiplexer
  - To divide total transmission bandwidth into frequency channels corresponding to the amplification chains
  - Selective filters
    - sufficiently steep slopes to avoid multiple paths through adjacent amplifying chains
    - sufficiently flat response curve in the pass band to keep distortions to tolerable levels

Communication Payload (cont.)

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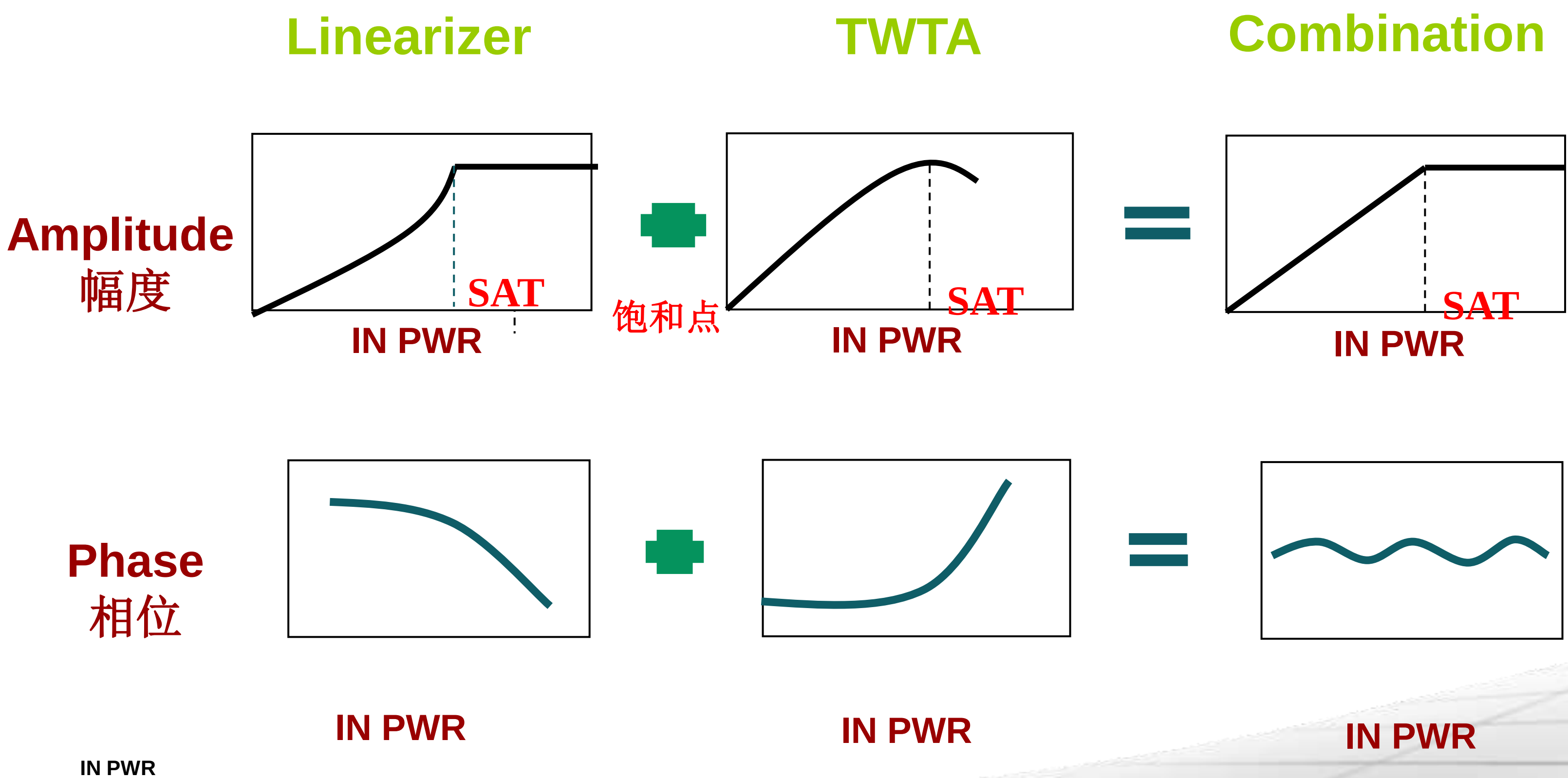
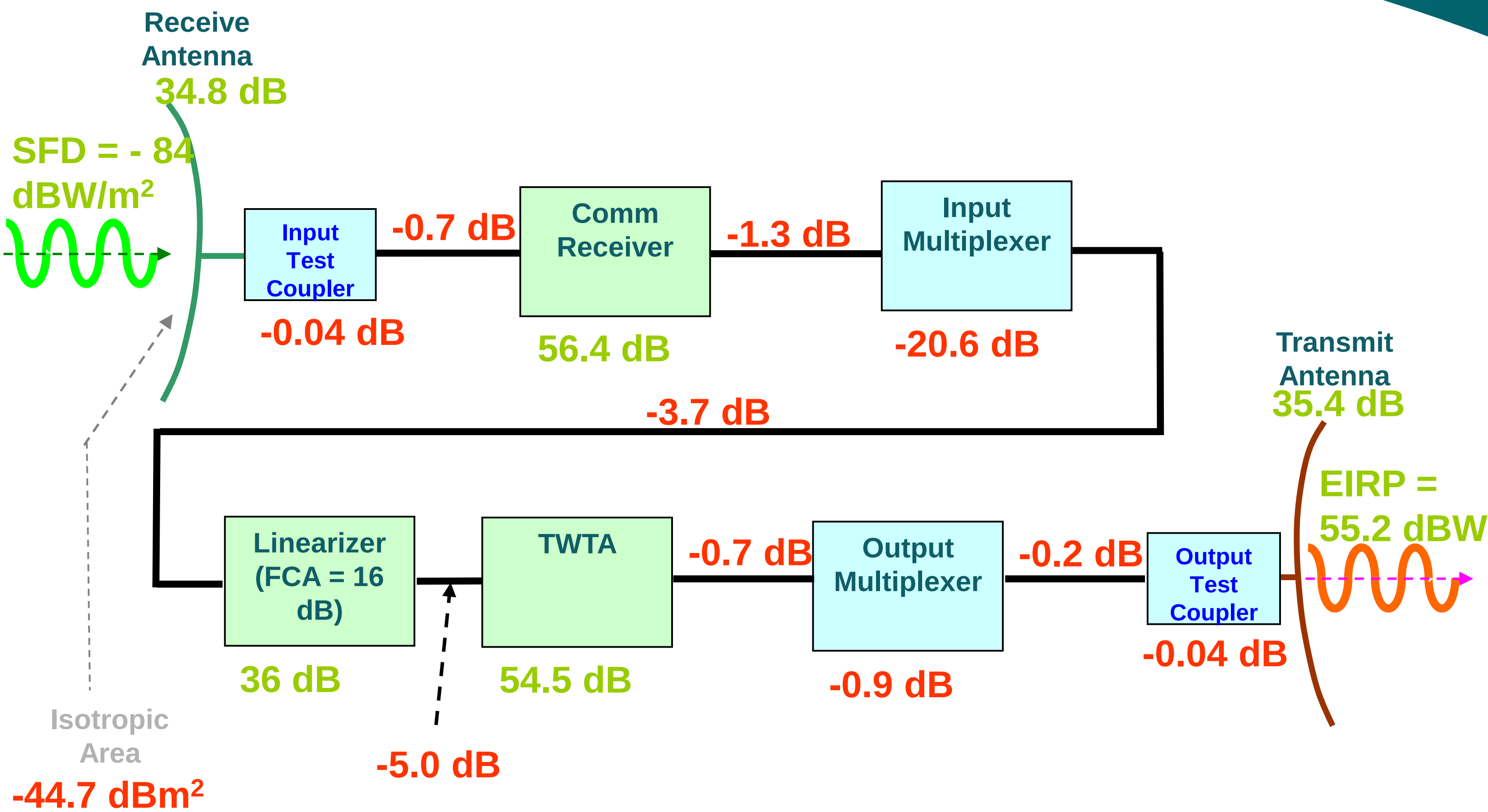
- ❖ Linearizer
  - ➢ Increasing linearity performance of the TWTA
  - ➢ Maintaining constant phase delay across entire channel
  - ➢ Adjusting the overall transponder gain level



Communication Payload (cont.)

- TWTA
  - Traveling wave tube amplifier
  - Non-linear active device
  - Typical gain of 50 to 60 dB
    - ⇨ higher downlink power, higher C/N, higher receive quality
- OMUX
  - Output Multiplexer
  - TWTA outputs combined together, then into transmit antenna
  - Reject the out-of-band harmonics and spurious noises

Ku-band Transponder Gain / Loss Budget



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Telemetry, Command and Ranging

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- TC&R
  - Telemetry, command and ranging
  - Providing two-way information flow between S/C and E/S
- Telemetry
  - Gathering, processing and transmitting S/C data to control station so that S/C configuration and health can be monitored
- Command
  - Decoding and routing uplinked command to target units for S/C re-configuring, re-orienting or re-positioning
- Ranging
  - Providing a path to receive ranging tones and re-transmit them to originating ground control station
  - Range between E/S and S/C can be obtained by comparing phase difference between waveforms of transmit and receive tones

Telemetry

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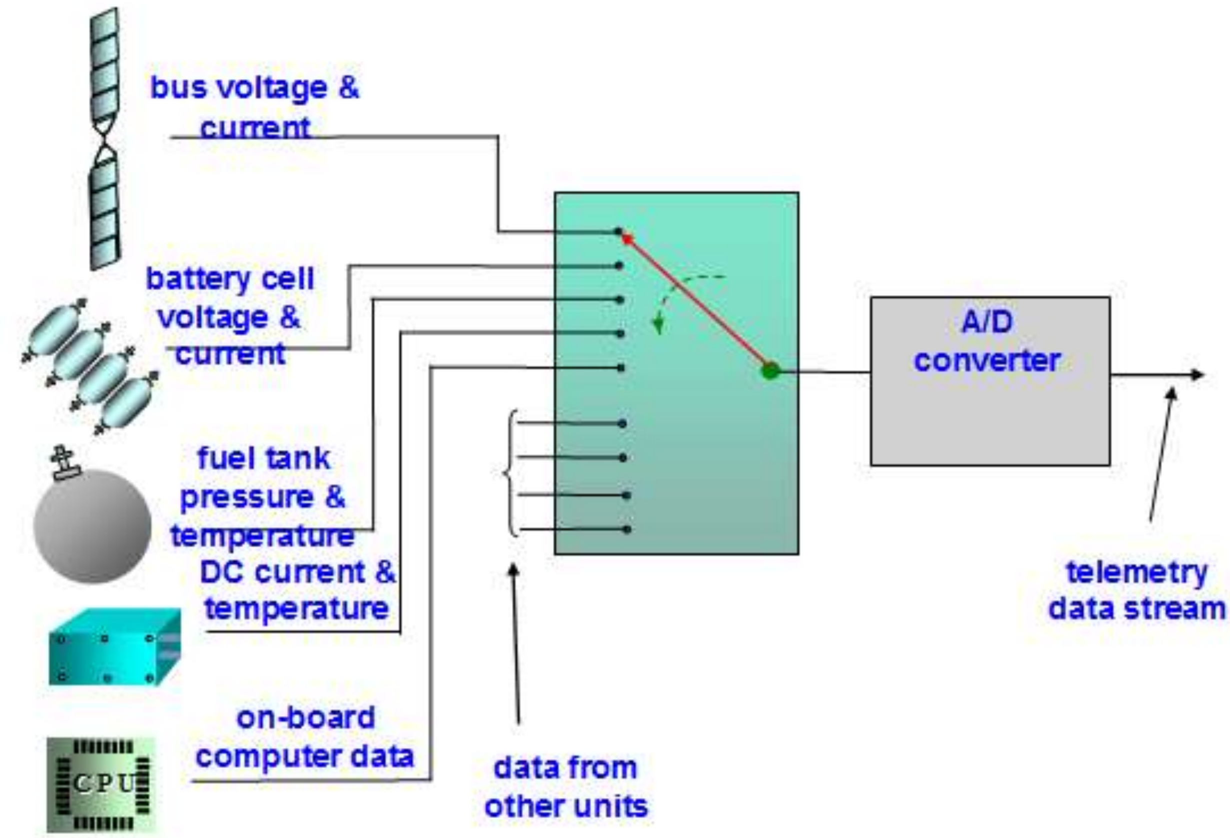
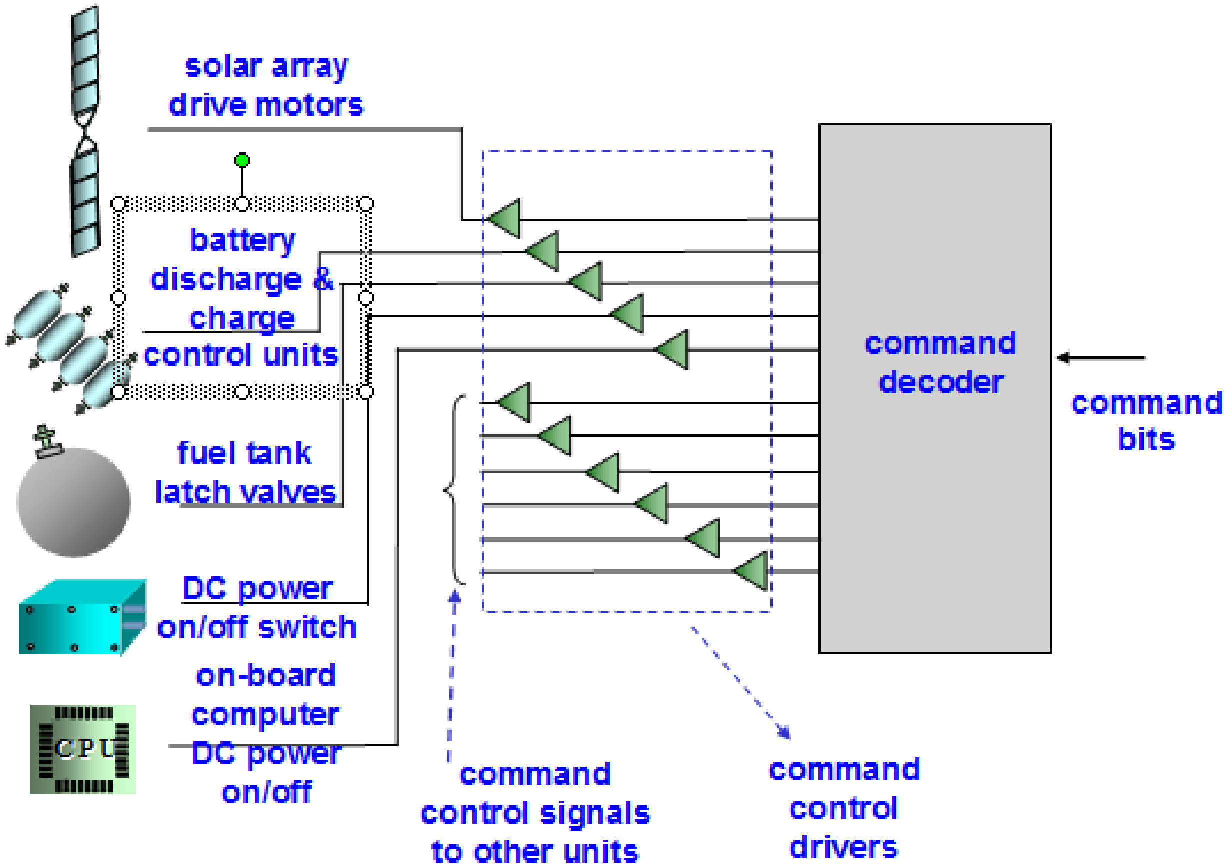
- ❖ Telemetry circuit
  - ➢ Gathering operational parameters
  - ➢ Coding them into telemetry signals
  - ➢ Transmitting them to the earth



Command

❖ Tele-command circuit
  - ➢ Receiving command signals from the earth
  - ➢ Decoding the commands
  - ➢ Distributing them to relevant subsystems



Ranging

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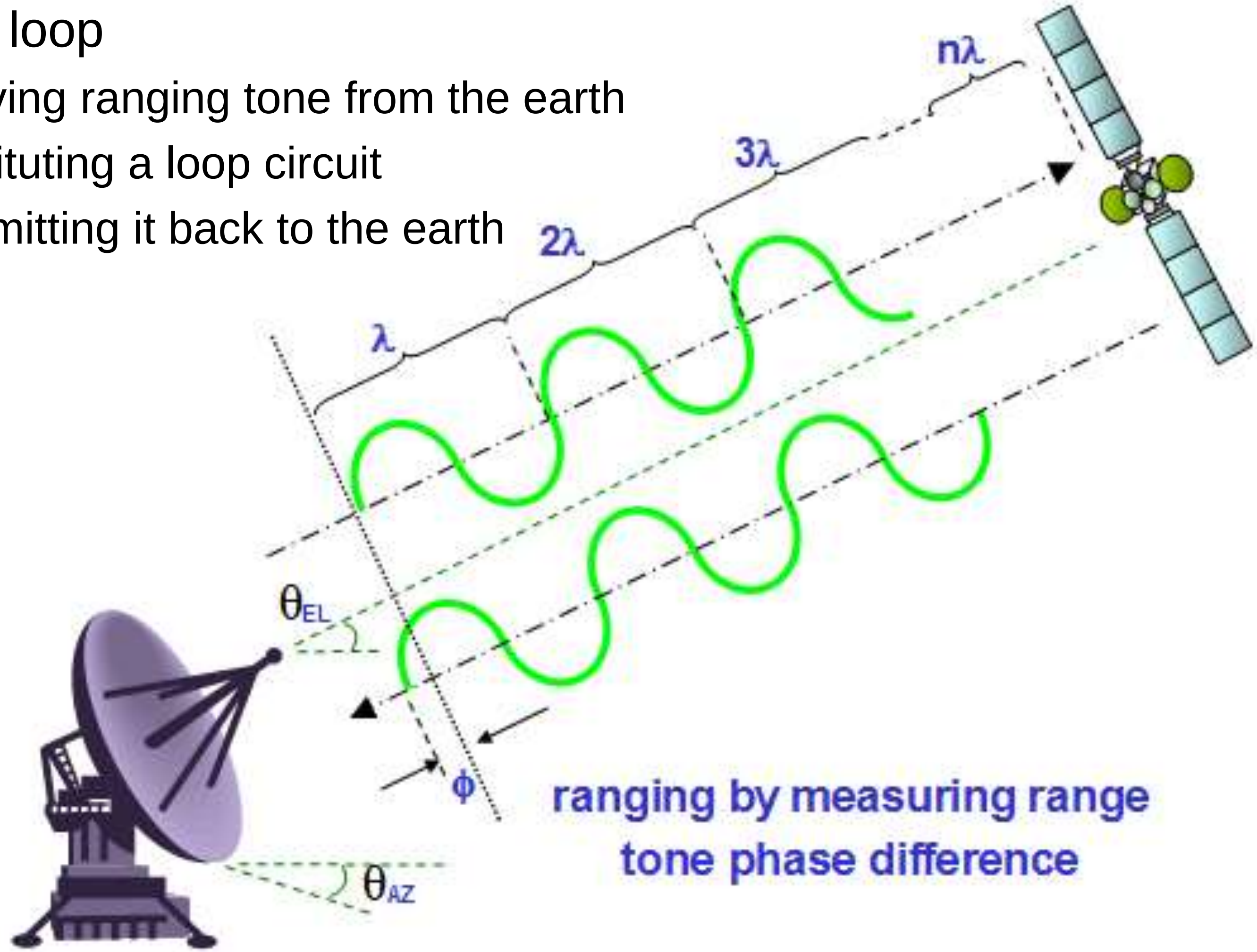
- ❖ Ranging circuit
  - ➢ Supporting satellite tracking and ranging by control station
  - ➢ Ranging loop
    - ⇨ receiving ranging tone from the earth
    - ⇨ constituting a loop circuit
    - ⇨ transmitting it back to the earth



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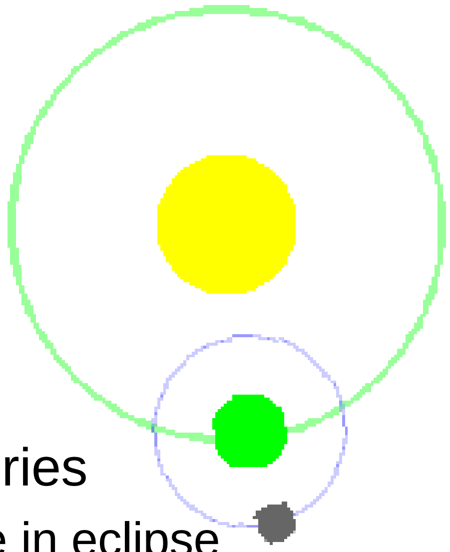
Electrical Power Subsystem

- DC power
  - A capacity scale of satellite bus
  - Typically 2 to 18 kW for communication satellites
- Power subsystem
  - Face-mounted solar panels
    - convert solar energy into electrical power
    - for payload and bus operation and battery charging
  - Regulator board and associated batteries
    - storing and supplying power for usage in eclipse



Solar Arrays and Batteries

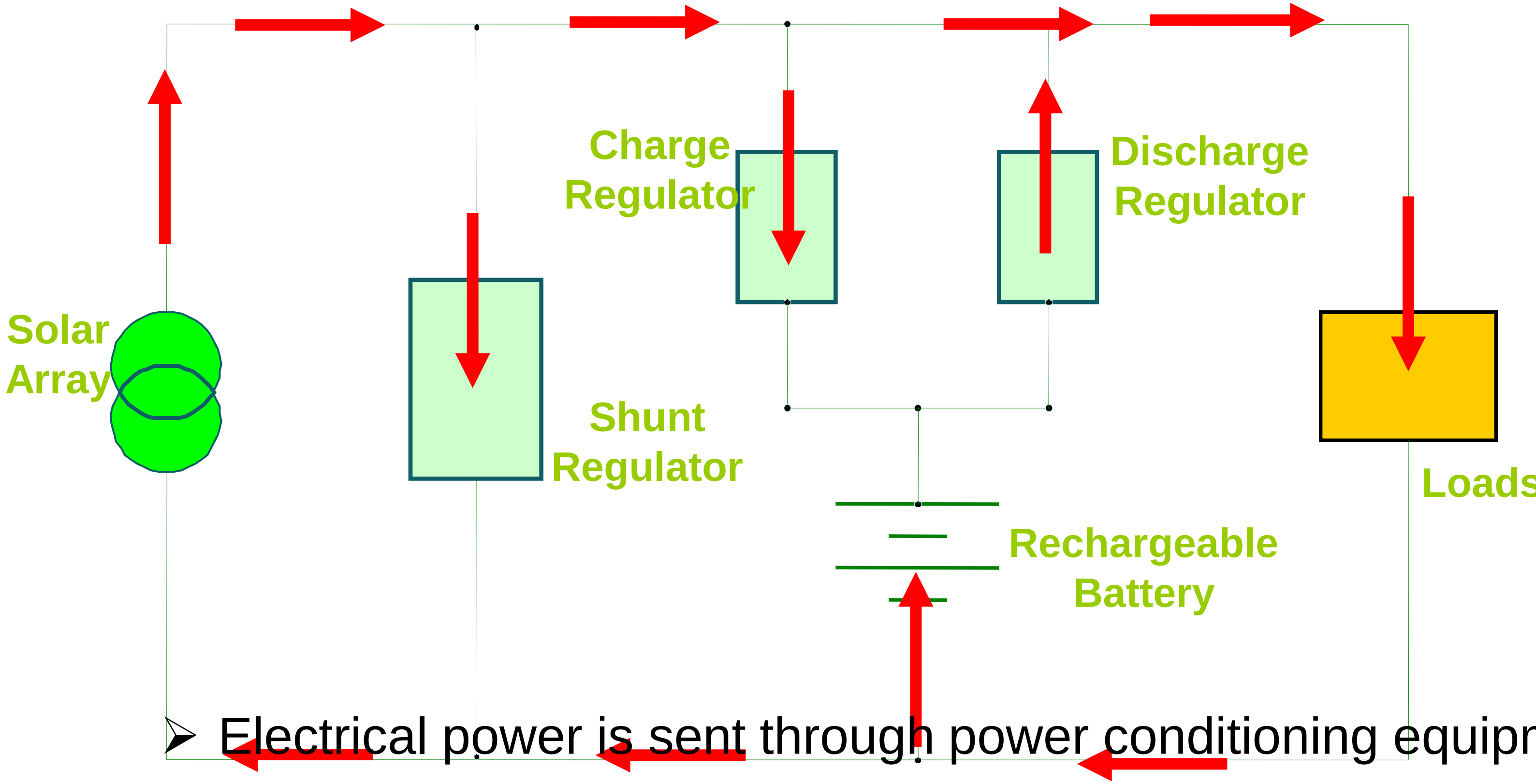
CHINA APMT

- ❖ Solar arrays
  - ➢ 2 deployable solar wings
  - ➢ Each wing consists of 3 to 5 panels
  - ➢ Silicon solar cells: transfer solar energy to electricity
  - ➢ Each panel is covered with solar cells (silicon or gallium arsenide) connected in series and in parallel
  - ➢ Aligned with the earth's N-S axis
  - ➢ Each wing is made to face the sun by an electric step motor which turns at 1rev./24hrs
- ❖ Rechargeable batteries
  - ➢ Power supply before solar wings deployed
  - ➢ Power supply in eclipse
    - ⇨ charging at low rate with the sunlight
    - ⇨ discharging to provide electrical power during eclipse period

EPS Functional Block Diagram

CHINA APMT

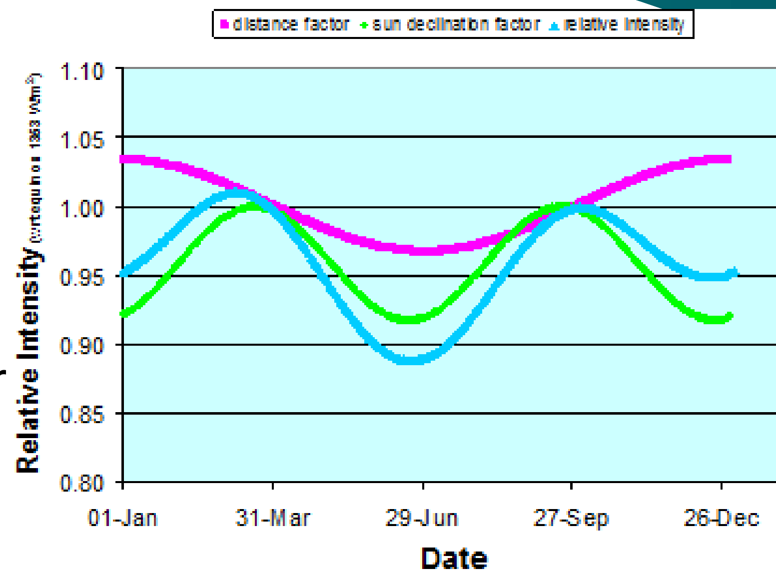
❖ Regulators

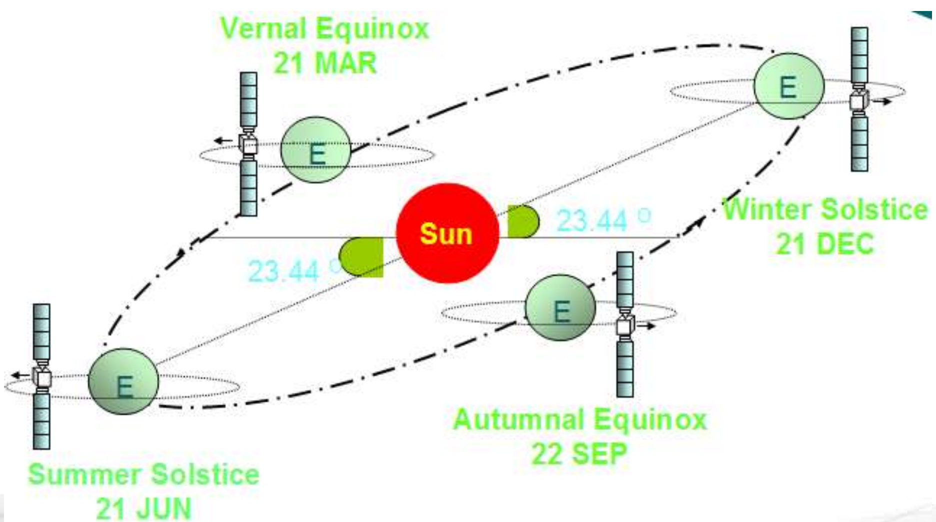


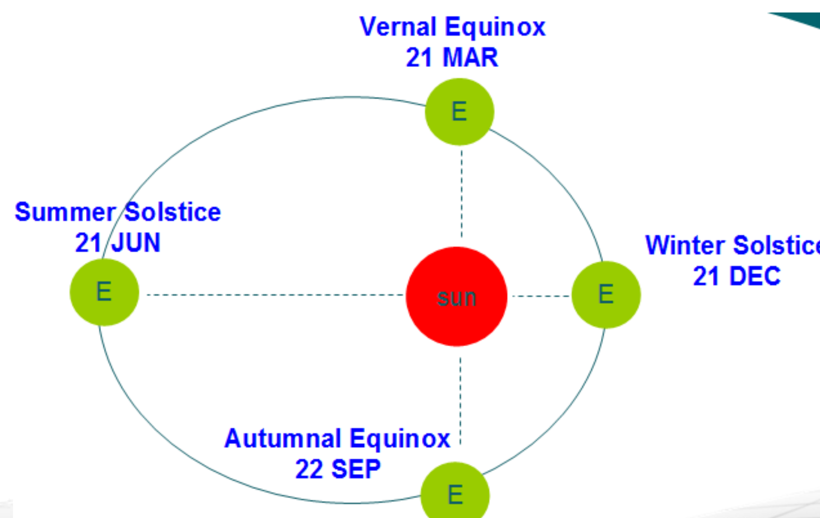
- Electrical power is sent through power conditioning equipment
- Then passes through a power distribution unit over an electrical bus to other spacecraft components
- Batteries are typically connected to the bus via a battery charge regulator

Yearly Variation of Solar Radiation Intensity

- Solar radiation intensity
  - Higher in vernal and autumnal equinoxes than in summer and winter solstices for the variation at sun light angle
  - Higher in summer than in winter for the distances between the sun and the earth







Life Variation of Solar Array Power

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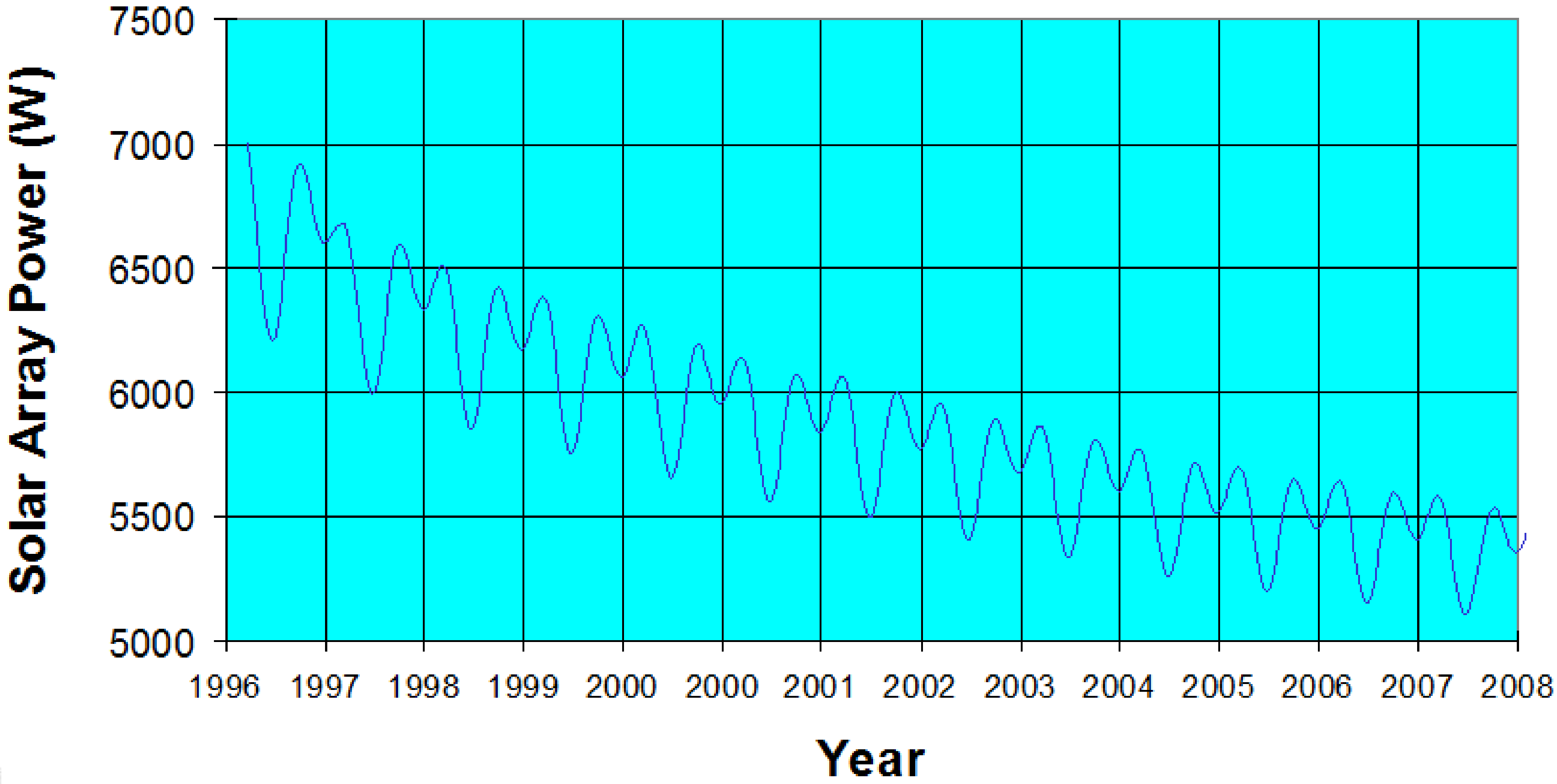
- Solar array power
  - Variation in every year
  - Low down in life time



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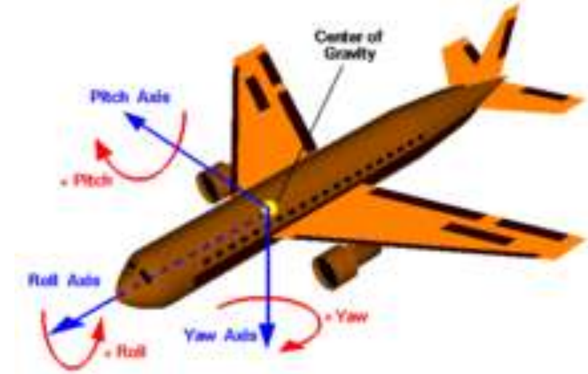
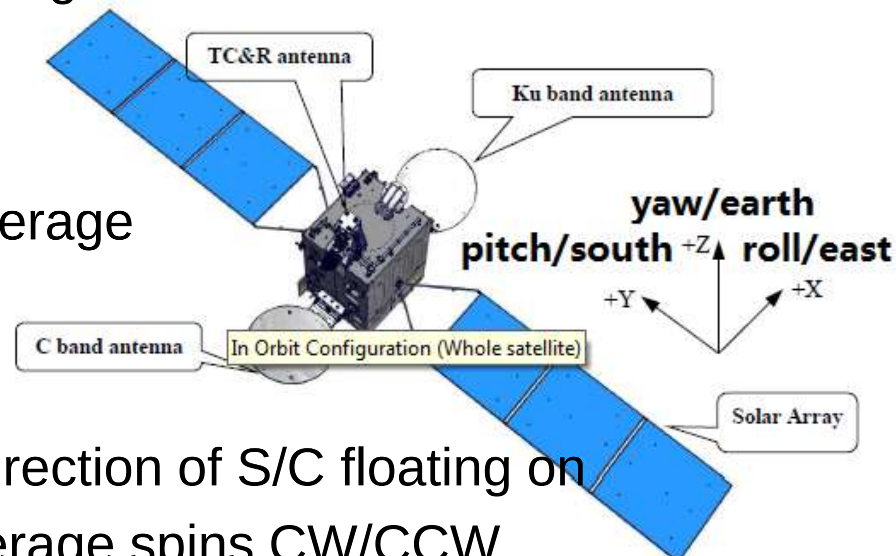
On-station Coordinates

CHINA APMT



- ❖ Three-dimensional coordinates
  - ➢ Carry forward the axes to control the attitude of a plane
- ❖ Roll
  - ➢ Pointing to east, the direction of S/C flying to
  - ➢ Roll rotation: antenna coverage shifts to N/S
- ❖ *Pitch*
  - ➢ Pointing to south
  - ➢ Pitch rotation: antenna coverage shifts to E/W
- ❖ *Yaw*
  - ➢ Pointing to the earth, the direction of S/C floating on
  - ➢ Yaw rotation: antenna coverage spins CW/CCW



Attitude Control and Station Keeping

- Attitude and orbit control subsystem
  - Sensors: to measure vehicle orientation
  - Flight software: to offer control algorithm
  - Actuators: to re-orient the S/C, and keep orbital position
- Attitude control
  - Automatically executed by ACS
  - Earth-pointing: keeping antennas in the right directions
  - Sun pointing: positioning solar arrays towards the sun
- Station keeping
  - Manually ordered by TT&C station
  - To counteract the movement of a satellite witch be affected by the gravitational field of the sun, the moon, and the earth
  - The amount of movement can be predicted using some complicated mathematical equations

Equipments of ACS

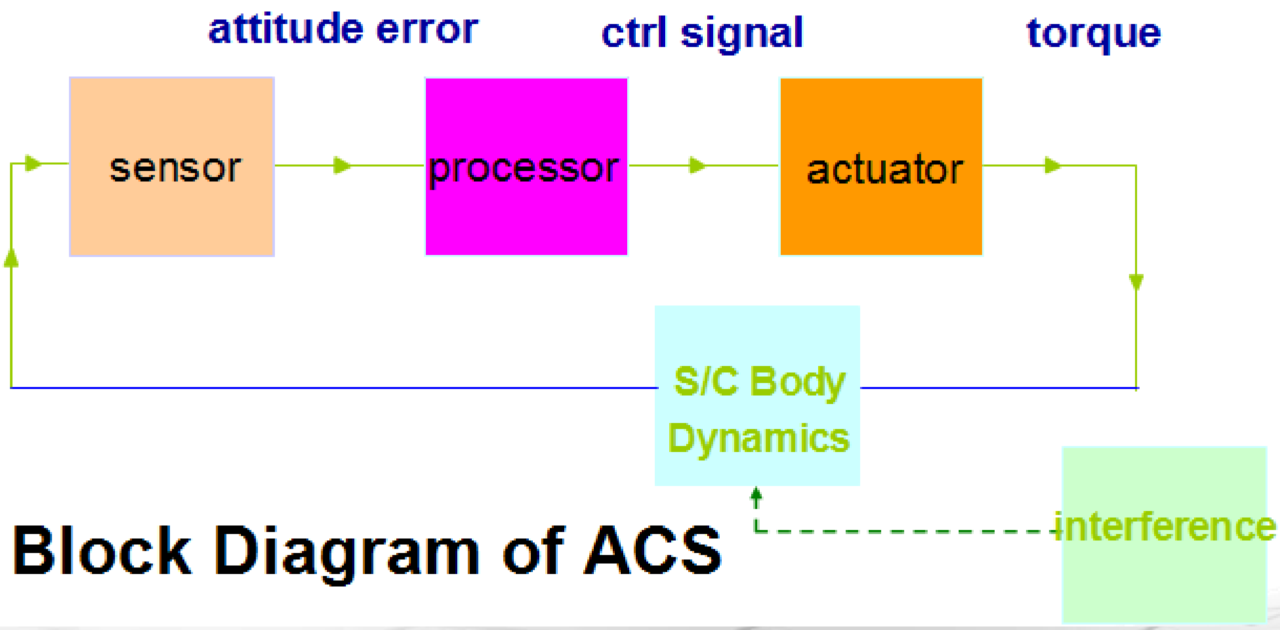
CHINA APMT

- Sensors
  - To detect attitude and position data
  - Gyro assembly and fiber optic gyro: offers roll and yaw angles
  - Sun sensor: transfer orbit
  - Earth sensor: offers pitch and roll angles
  - Star tracker: roll, yaw and pitch
- Actuators
  - To apply the torques and forces needed to re-orient the vehicle to a desired attitude or in the correct orbital position
  - Reaction wheels: used for attitude control
  - Thrusters: used for station keeping
  - Solar array drive mechanism: to keep arrays facing the sun

Equipments of ACS (cont.)

CHINA APMT

- ❖ On-board processor
  - ➢ Processing the information offered by sensors
    - ⇨ accurate data collection
    - ⇨ subsequent data interpretation
  - ➢ Selecting proper actuator
  - ➢ Short propulsive maneuvers executed in the right direction
  - ➢ Attitude corrected to accomplish precise pointing



Block Diagram of ACS

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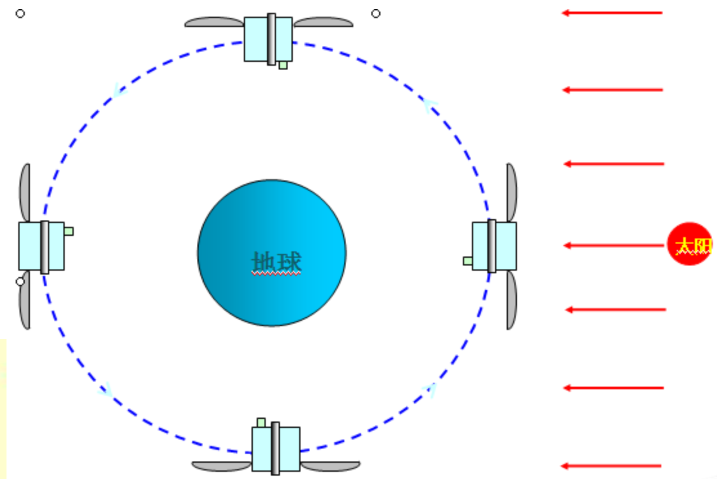
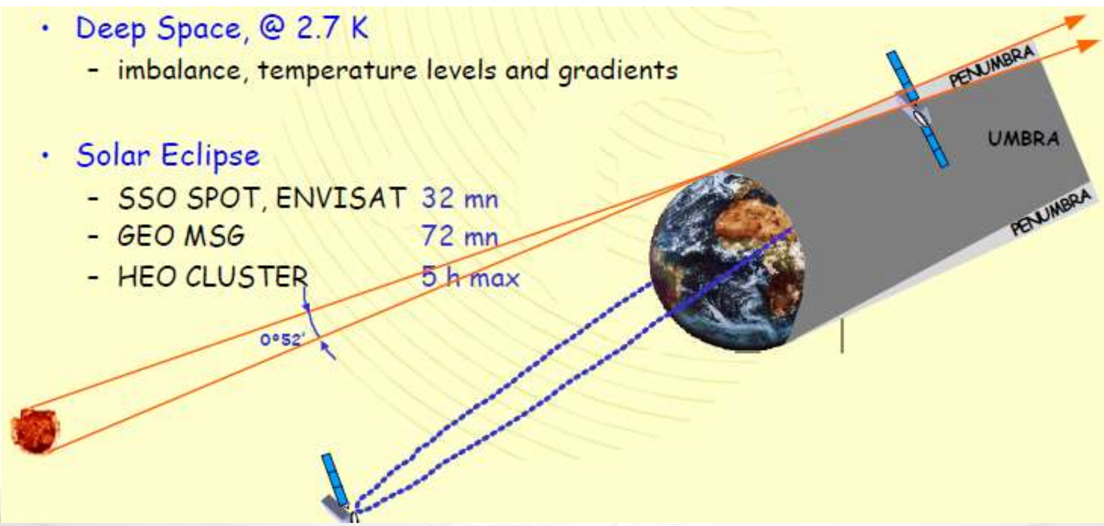
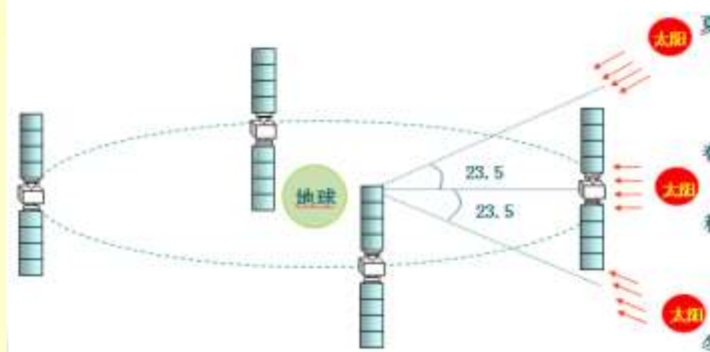
Thermal Environment

- ❖ Vacuum environment
  - ➢ Presence of sun illumination, the temperature at S/C surface will heat up quickly
  - ➢ Absence of sun illumination especially during sun eclipse, it will fall down extremely
- ❖ Variation of solar irradiation
  - ➢ Daily and annually
  - ➢ Eclipse







Why Thermal Control

CHINA APMT

- Thermal control
  - Can be composed both of passive and active items
  - Protecting the equipment from too hot temperatures
    - by thermal insulation from external heat fluxes
    - or by proper heat removal from internal sources
  - Protecting the equipment from too cold temperatures
    - by thermal insulation from external sinks
    - by enhanced heat absorption from external sources
    - or by heat release from internal sources
- Reference

  http://www.tak2000.com/data/Satellite_TC.pdf

How Thermal Control

CHINA APMT

- Methods
  - Reflection
    - optical solar reflector, thermal control coating
  - Insulation
    - multi-layer insulation for external surface
  - Radiation
    - radiators on external N/S side to reject heat to space
  - Heating
    - heaters for propellant lines, thrusters, main engine, and other equipments from too cold environment
  - Conduction
    - heat pipe spreading out heat generated by HPA and other internal active parts

Passive Thermal Control

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- MLI
  - Multi-layer Insulation
  - Protecting spacecraft from excessive heating and cooling
- OSR
  - Optical Solar Reflectors
  - Improving heat rejection capability of the external radiators
  - Reducing absorption of external solar flux
- Coating
  - Changing thermo-optical properties of external surfaces
- Thermal fillers
  - Improving thermal coupling at selected interfaces
- Thermal doublers
  - Spreading heat dissipation under unit and on the radiator surface

Active Thermal Control

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- ❖ Thermostatically controlled resistive electric heaters
  - ➢ Keeping equipment temperature above its lower limit during the mission cold phases
- ❖ Fluid loops
  - ➢ Transferring the heat dissipated by equipment to the radiators
  - ➢ Single-phase loop, controlled by a pump
  - ➢ Two-phase loops, composed of heat pipes (HP), loop heat pipes (LHP) or capillary pumped loops (CPL)
- ❖ Thermoelectric coolers
- ❖ Louvers
  - ➢ Changing heat rejection capability as a function of temperature

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Propulsion Subsystem

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- ❖ Conventional propulsion subsystem
  - ➢ Fuel and tanks
    - ⇨ launch mass: S/C weight at the beginning of life
    - ⇨ dry mass: S/C weight at the end of life
  - ➢ Pipes and valves
  - ➢ Thrusters
    - ⇨ keeping spacecraft in its assigned place in orbit
    - ⇨ unloading momentum wheels
  - ➢ Main engine
    - ⇨ bringing the spacecraft to its permanent position
- ❖ Thermal control
  - ➢ Monitoring component temperatures of propulsion subsystem
  - ➢ Preheating tanks and thrusters in preparation for a spacecraft maneuver

Function

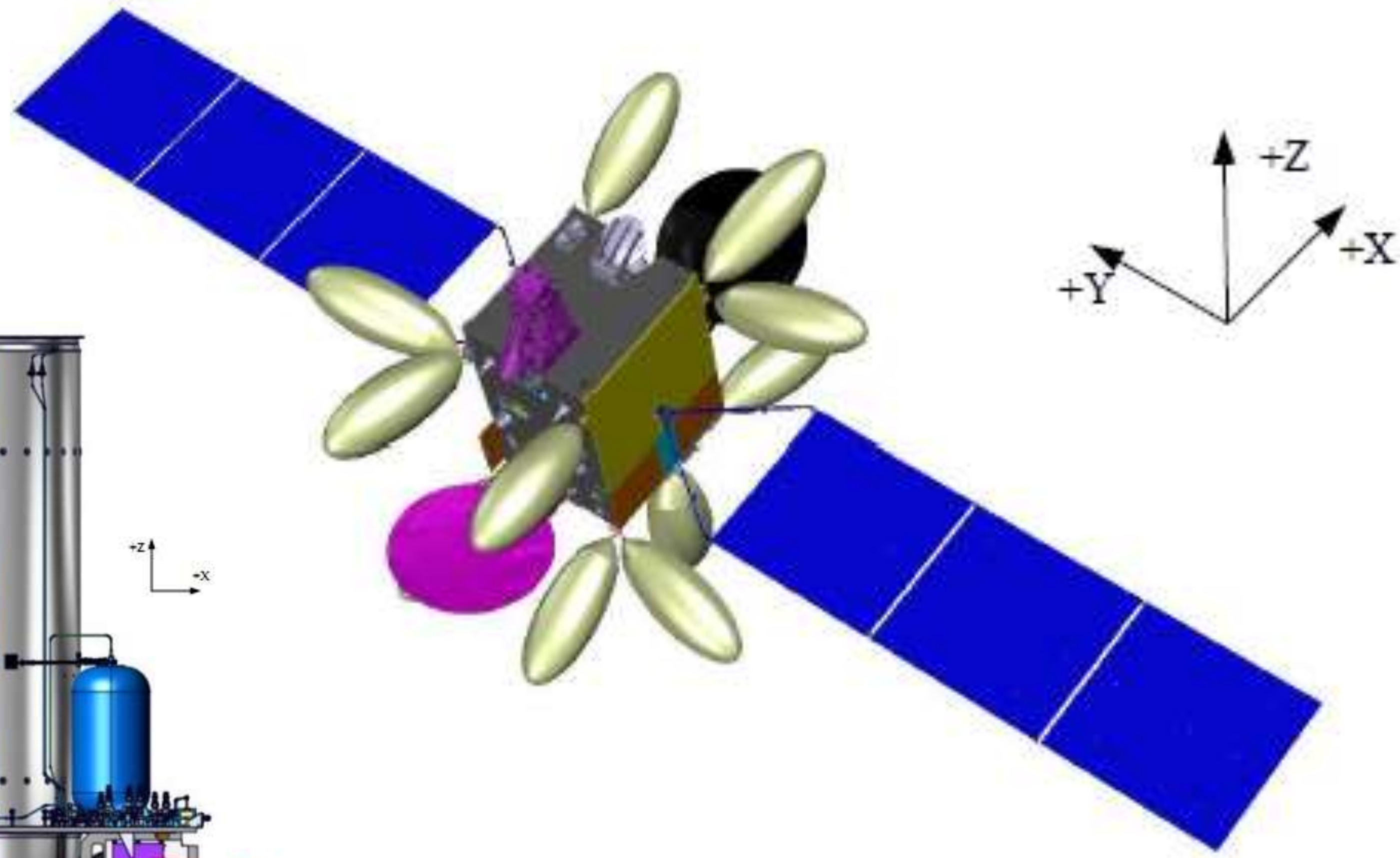
- Generating thrust and providing impulse
  - Firing at transfer orbit to achieve GEO orbit
- Providing impulse, maintaining S/C attitude and orbital position
  - During GEO operations
- Providing minimum impulse bits
  - During normal mode operation
  - For momentum wheel unloading
- Providing velocity change and attitude control
  - During station keeping maneuvers

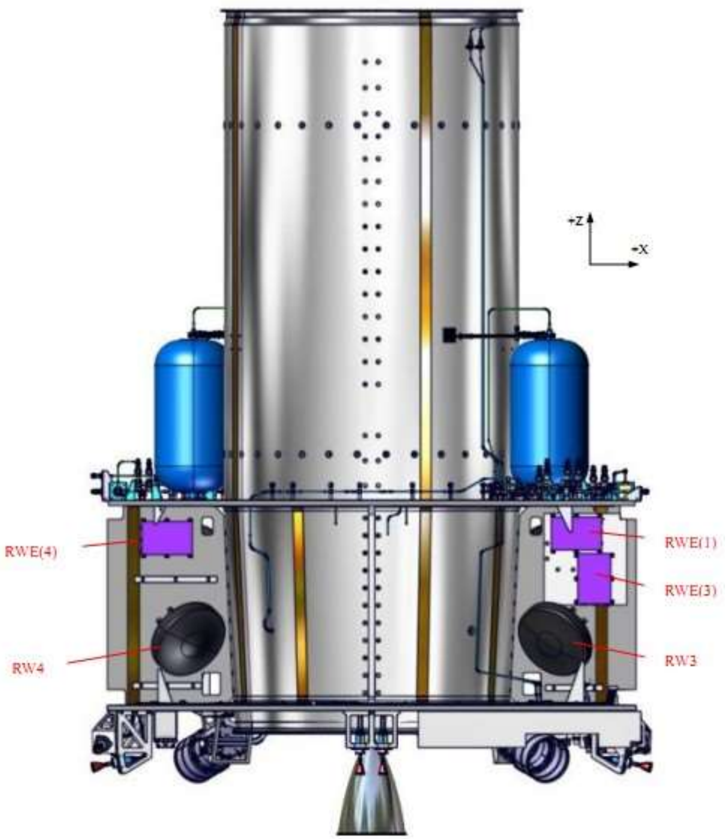
Functional Parts

CHINA APMT

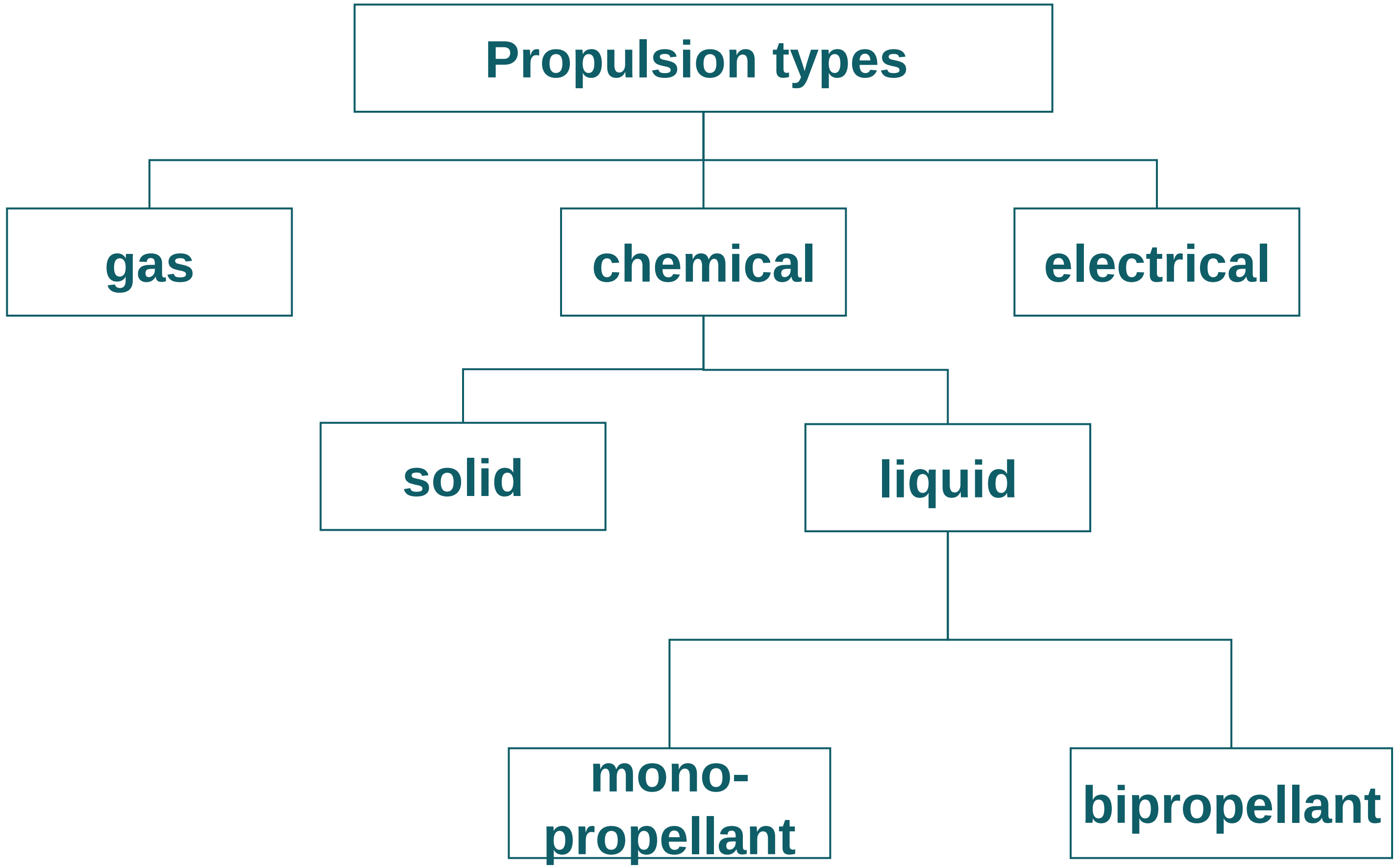
- Pressure supply and regulation
  - Helium tanks
    - providing helium gas as pressurant
  - Pressure regulation
    - pressurizing and regulating, valve checking and latching, helium filtering
- Propellant storage and distribution
  - Propellant storage
    - propellant tanks and management devices
  - Propellant distribution
    - pipes to LAE and thrusters
- Thrusters and main engine
  - LAE
    - liquid apogee engine
  - 16 thrusters
    - for attitude and orbit control

LAE and Thruster Plumes





Propulsion types



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Reference:

AsiaSat: Customer Training Materials, April 2004

Wikipedia

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