MOUDLE 5

Space Mission Operations

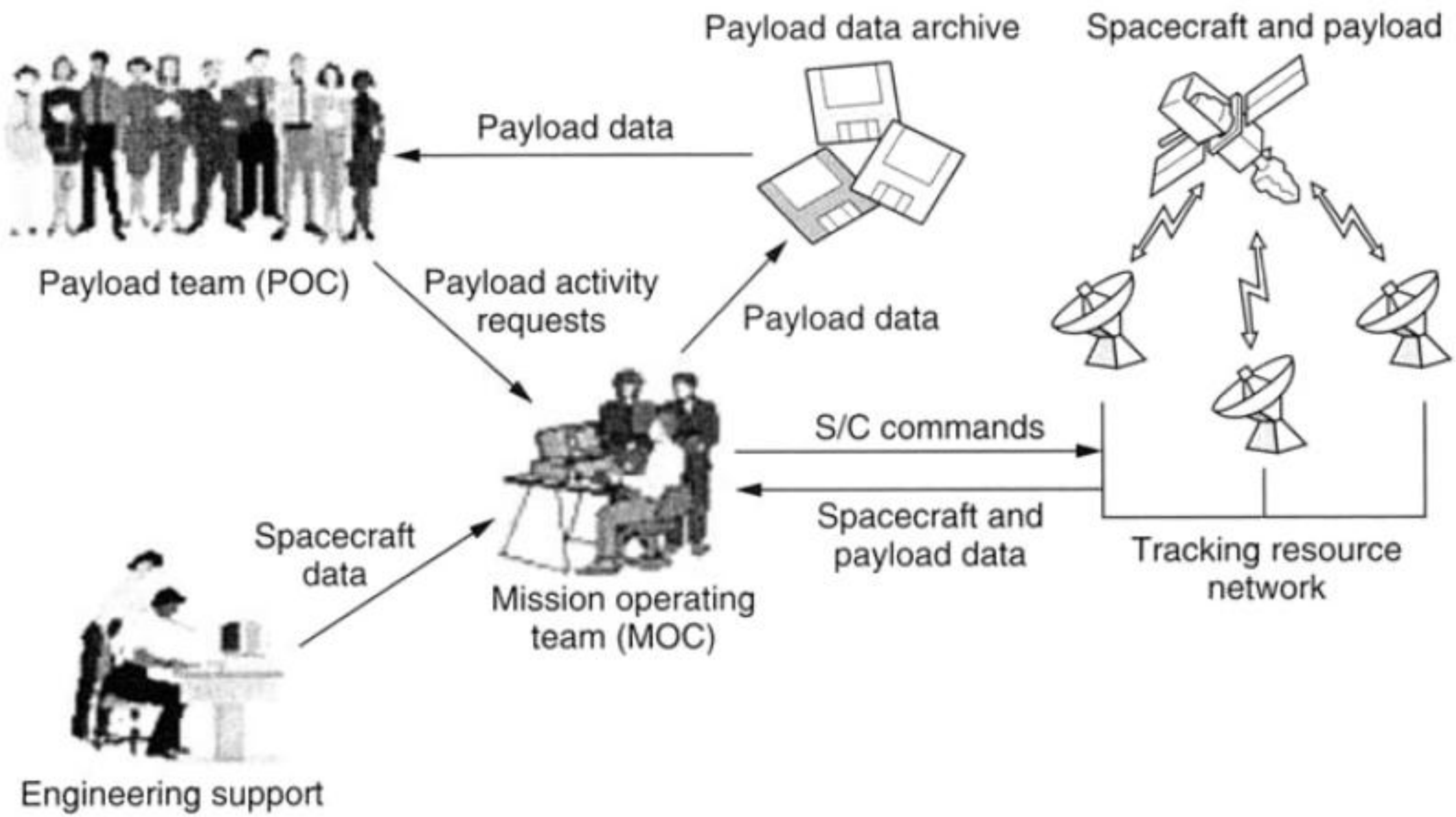
Supporting Ground System Architecture and Team Interfaces

- ✓ Mission Operations Center (MOC)
- ✓ Tracking Network
- ✓ Payload Operations Center (POC) and Payload Data Archive
- ✓ Spacecraft and Payload
- ✓ Operational Engineering Support
- ✓ Core Mission Operations team

INTRODUCTION

- Flight systems, including spacecraft and its payload.
- Tracking systems, including antennas and networks for two-way communications with flight systems.
- Ground systems, including the mission operations center (MOC), payload operations center (POC), data archive and distribution systems as required, and network infrastructure.
- Operations personnel, including core operations team in the MOC and supporting personnel in the POC, spacecraft engineering support, and management team.

High-level space mission operations architecture



Mission Operations Center (MOC)

- Real-time spacecraft commanding and monitoring system
- Flight system performance and status assessment systems
- Mission planning and command scheduling tools
- Engineering data archive
- Flight simulators

Spacecraft and Payload

- Power generation and distribution
- Onboard communications and data handling
- RF communications and tracking support
- Guidance and control (passive or active)
- Propulsion (optional)
- Mechanical structures

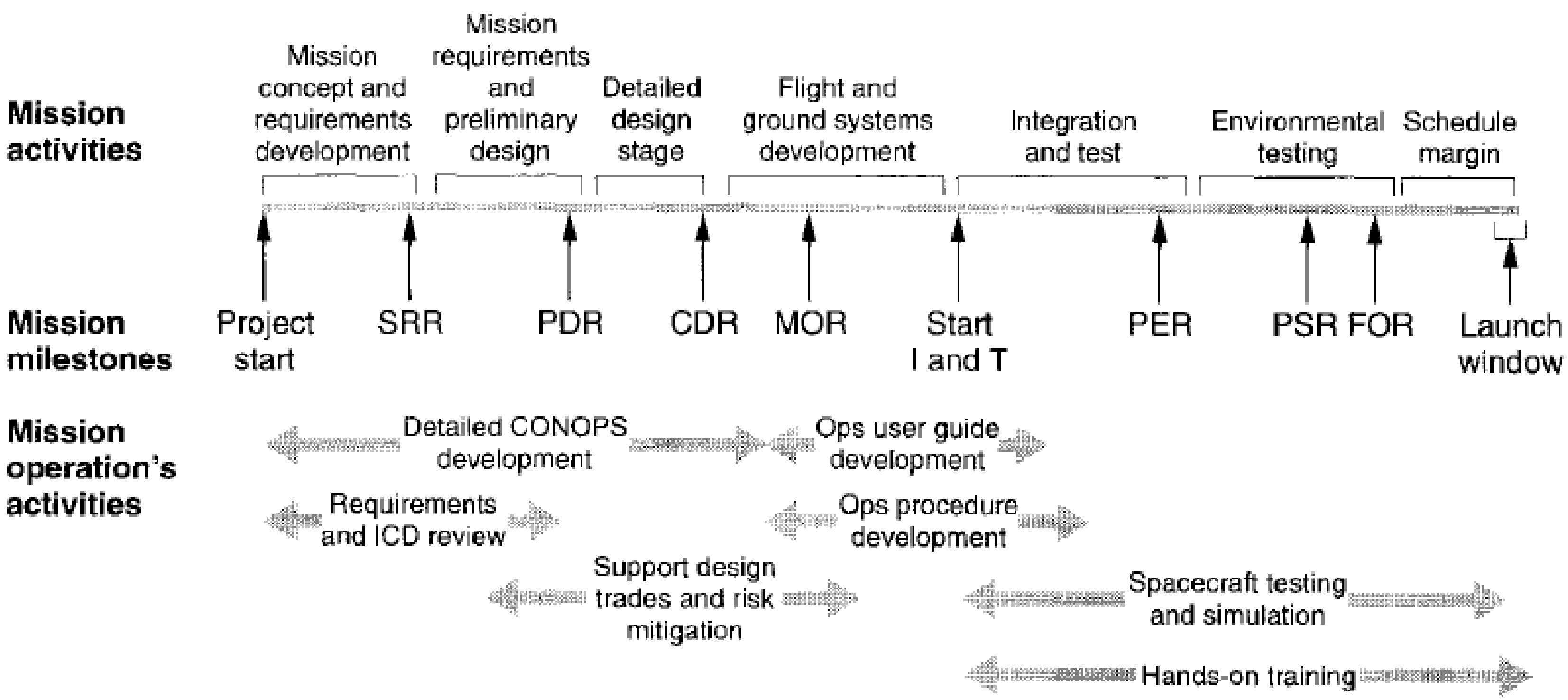
Core Mission Operations team

- Flight and ground problem reporting and resolving
- Real-time command and monitoring
- Mission planning
- Spacecraft activity scheduling
- Payload activity scheduling (as required)
- Command scheduling and command load preparations
- Spacecraft performance assessment

Mission Phases and Core Operations Team Responsibilities

- Mission Concepts Development Phase
- Mission Requirements and Design Phase
- Flight and Ground System Development Phase
- Integration and Environmental Testing
- Launch and Commissioning
- Prime Mission Phase

Mission timeline: pre-launch



Mission Concepts Development Phase

- Mission operations planning, control, and assessment strategies
- Spacecraft tracking resources utilized
- Ground systems and networks required, and plan for maintenance
- Data flows and interfaces between all mission elements
- Staffing level distribution over time
- Expected operational scenarios for key mission events including a “day in the life” of the mission

Flight and Ground System Development Phase

- Operations procedures and checklist development
- Operations user guide documentation
- Telemetry and command database development support
- Spacecraft and instrument command sequence development

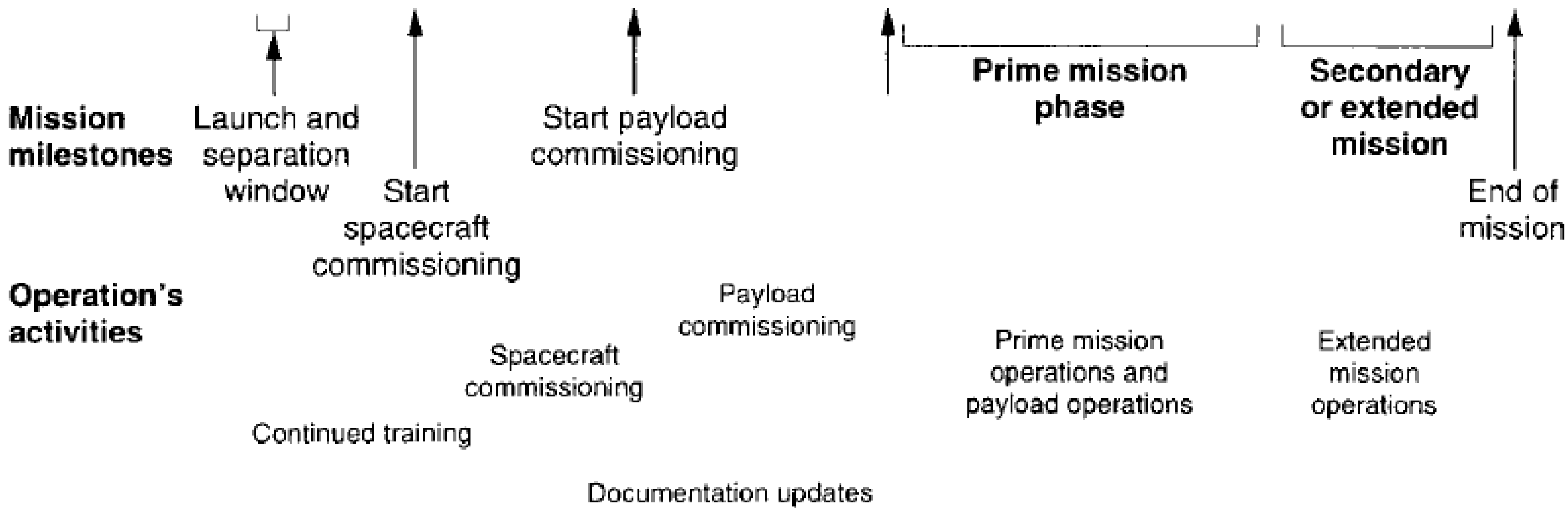
Prime Mission Phase

- Real-time flight operations are those conducted during the spacecraft contacts
  - Real-time commanding and stored command loading
  - Ephemeris (orbit prediction) updates for spacecraft pointing control
  - Flight recorder data playbacks of engineering and payload data
  - Real-time health and status assessments of flight systems
  - Monitoring of critical operations activities
  - Spacecraft tracking as required for orbit determination
  - Contingency handling

Prime Mission Phase continues..

- Offline activities include the mission planning function and long-term assessment of spacecraft performance
  - Detailed assessment of spacecraft systems
  - Planning of future spacecraft and payload events
  - Command scheduling of future stored command loads
  - Testing of command loads and updated command scripts
  - Archiving and distribution of mission payloads data
  - Evaluation of payload results and adjustments to mission plan as required
  - Attitude and orbit maneuver planning to meet mission objectives

Mission timeline: post-launch



Mission Diversity

- Spacecraft’s orbit or trajectory
- Mission sponsor and payload type
- Spacecraft attitude control approach
- Spacecraft Orbit

Summary of operations characteristics versus mission characteristics		
Spacecraft orbit	LEO	Short contacts, high data rates, negligible round-trip-light-times (RTLTs), repetitive operation, ground and flight systems automation candidate
	MEOIGEO	Longer contacts up to continuous coverage, moderate data rates, minimal RTLTs (< 1 sec), candidate for ground-based autonomy, low risk, steady state operation
	Deep-space	Periodic contacts, low data rates, long RTLTs, unique event-driven operations, flight-based autonomy, large aperture antennas, higher risk levels, science payloads.

Summary of operations characteristics versus mission characteristics continues...		
Spacecraft type	3-axis	Flexible but complex operation, higher risk, can be highly automated
	Spin	Simpler implementation and low risk, less flexible, manual intensive
	Gravity gradient	Simple passive approach for orbiters, little flexibility, simple operation.
Mission sponsor (all U.S.)	NASA	Science and technology driven missions, moderate security, moderate risk/moderate cost.
	DOD	National defense and technology driven, highest security, moderate risk/moderate cost
	Commercial	Communications remote imagery applications, lower security, low risk/low cost

Spacecraft Orbit

- Low to medium altitude Earth orbiting (LEO)
- Medium or geosynchronous Earth orbiting (ME0 or GEO)
- Deep space (heliocentric

Standard Operations Practices

- Concept of Mission Operations
- Configuration Management
- Application of Flight Constraints
- Training and Certification
- Real-Time Operations
- Documentation
- Contingency Planning
- Spacecraft Performance Assessment

Configuration Management

- Scripts and procedures
- Operational databases (telemetry and command)
- Flight and ground software
- Spacecraft command loads
- Ground system hardware and networks
- Spacecraft simulation tools
- Critical documentation
- Spacecraft autonomy rules and onboard parameters
- Flight constraints

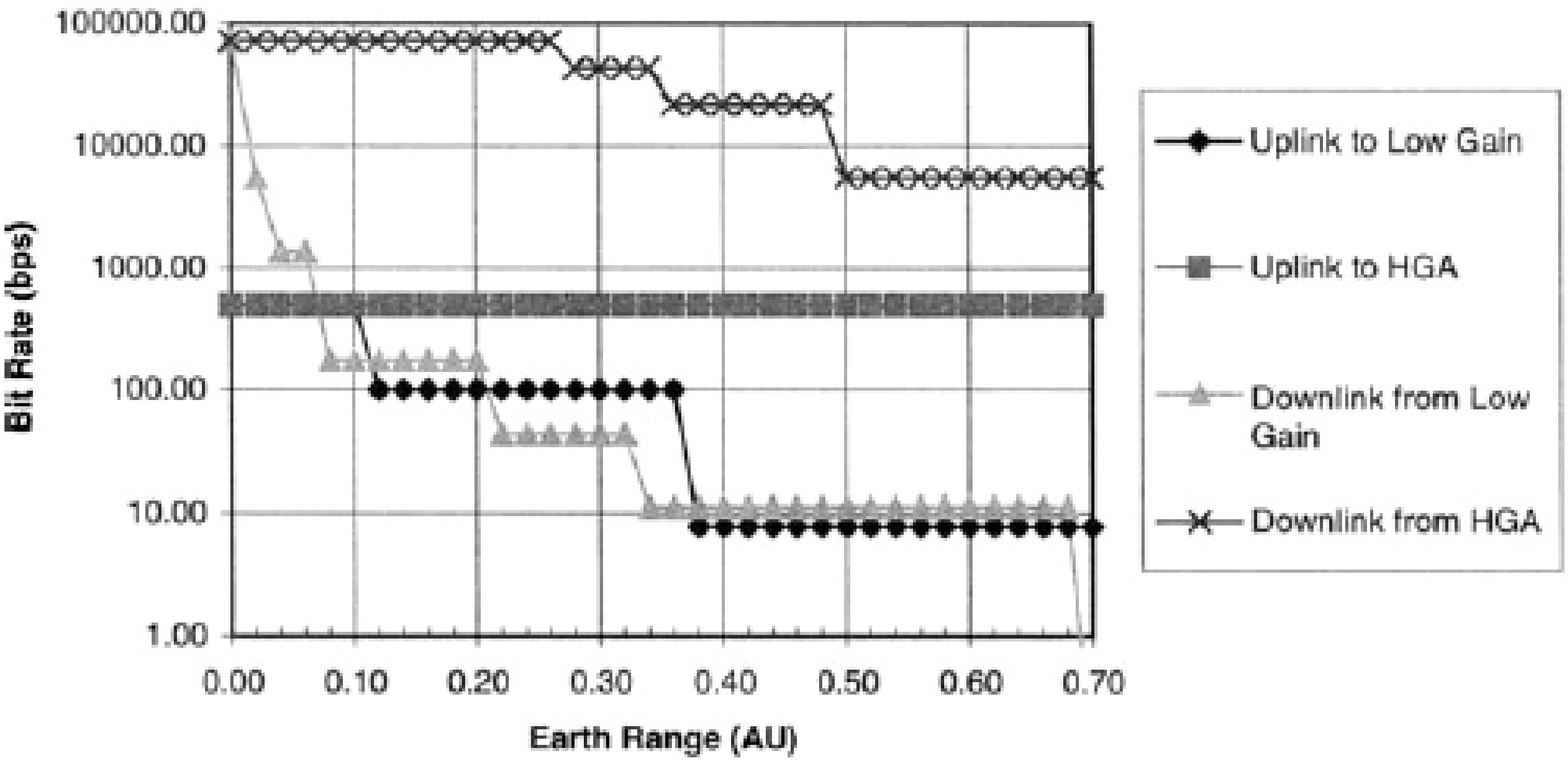
Application of Flight Constraints

- Operating spacecraft pointing relative to Sun bounds (for power or thermal control)
- Sensor pointing constraints
- Command ordering (i.e., “command *y* must always follow command x”)
- Command timing (i.e., “command ***y*** must always be separated by 2 seconds from
- Power and heater management
- Configuration guidelines (i.e., “transmitter 1 shall always be connected to antenna
- Never do’s (i.e., “never turn off communications and data handling processor”)
- In the event (i.e, “in the event of under voltage, switch regulators”)
- On-time limitation (“never leave calibration lamp on for more than 1 minute”)

Documentation

- Concepts of operations
- Spacecraft and ground system user guides
- Text procedures for standard and contingency operations
- Plans for training and configuration management
- Schedules for work plans
- Operating constraints (flight rules)
- Operating logs

Assuming the predicted spacecraft signal strengths shown in the figure below (note logarithmic ordinate):



Bill rate capability versus Earth range.

problems

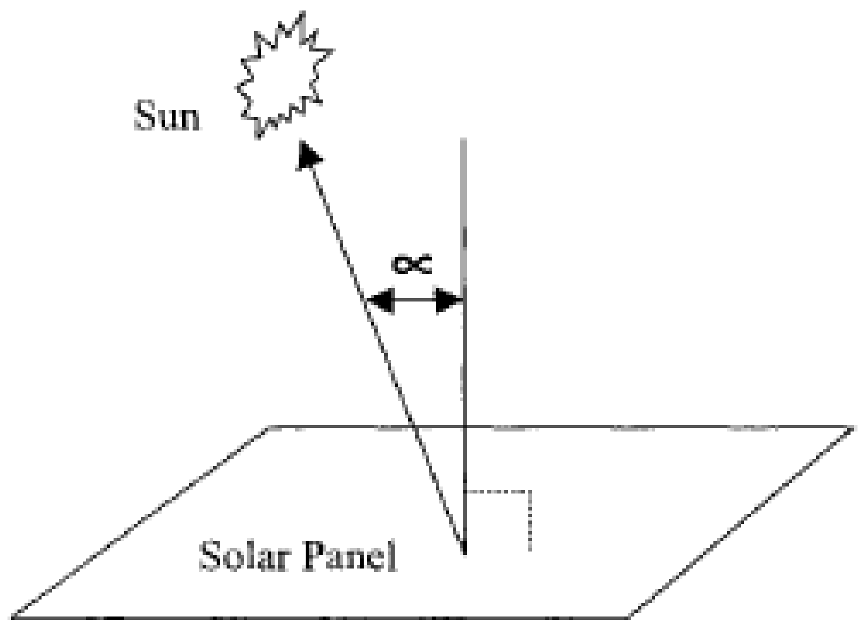
- (a) What is the maximum downlink bit rate possible at 0.6 **AU,** and which antenna should be used (parabolic high-gain antenna or omnidirectional low-gain antenna)?
  - ***Answer:*** 5.5 kbps on **HGA.**
- (b) How long would it take to downlink a 1 megabit image at this data rate?
  - ***Answer:*** 181.8 s or -3 min.
- ***(c)*** What is the maximum uplink bit rate and the preferred antenna at the same distance?
  - ***Answer:*** 500 bps on HGA.

Problems…

- (d) How quickly then could a 500 kilobit command load be uplinked? How long would it take on the low-gain antenna?
    - *Answer:* 1000 s on the HGA, or 13.8 h on the LGA.
- (e) Under what circumstances would you expect the low-gain antenna to be used, given these results?
    - *Answer:* The LGA has omnidirectional capability so it can provide communications when the parabolic antenna cannot be directed at Earth. However the LGA provides significantly lower data rates, hence it would be used only when HGA communications are not possible or practical, or when higher data rates simply are not needed.

Problems…

2. Assume 346 W is required to power a spacecraft and its instrument in a particular configuration. The spacecraft's solar panels can generate 500 W when the Sun's angle of incidence to the solar panels *(a)* equals zero (see figure).



Problems…

- (a) Assuming the power generated drops off according to the cosine law, how great can *a* be (amaxto) maintain a positive power balance?

  Answer: $\alpha_{\max} = 46.21°$

- (b) How does this **amaaxn** gle change if a 10% power margin is desired?

  Answer: $\alpha_{\max} = 40.43°$ with 10% power margin.

- (c) What is *a* later in the mission if power generation from the solar array is reduced (say from long-term degradation) by 10% and the 10% margin is still desired?

  Answer: $\alpha_{\max} = 32.24°$ with 10% power margin and 10% reduction in solar panel output.