INTRODUCTION TO SPACE SYSTEMS

Introduction to Space Systems

- Appropriate readings in the text:
  - Chapter 1 – Space in Our Lives (space systems overview)
  - Chapter 2 – Exploring Space (historical perspective)
  - Chapter 16 – Using Space (contemporary view of industry)
- Topics
  - Competitive Motivations
  - Space-based products and typical mission classes
  - Space system architecture and segment definitions
  - Space system control process
  - Payloads and bus subsystems
  - Environment and orbital constraints / drivers

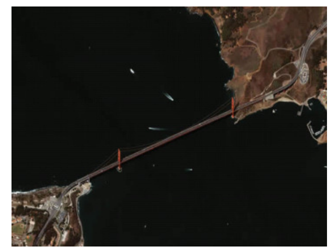
Space products/services - motivations

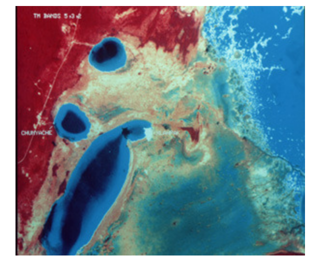
- Benefits of space-based products and services
  - Global view of Earth
  - Above Earth's atmosphere
  - Space environmental characteristics
  - *In situ* space characterization and exploration
  - Exploitation of resources
  - Pride and distinction

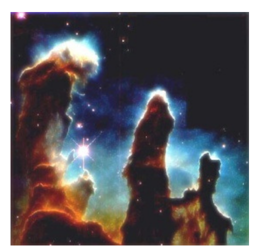
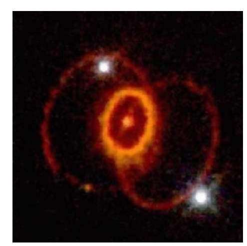
Space products/services – uses

- Communications
  - Phone / voice
  - Broadband
  - Direct TV/radio
- Remote Sensing
  - Weather – NOAA
  - Military
  - Land management – LandSat
- Navigation – GPS
- Science and Exploration
  - Hubble, Mars missions, etc.
- Emerging?
  - Materials Processing?
  - Tourism? Resource Harvesting?




Geoeye

NASA


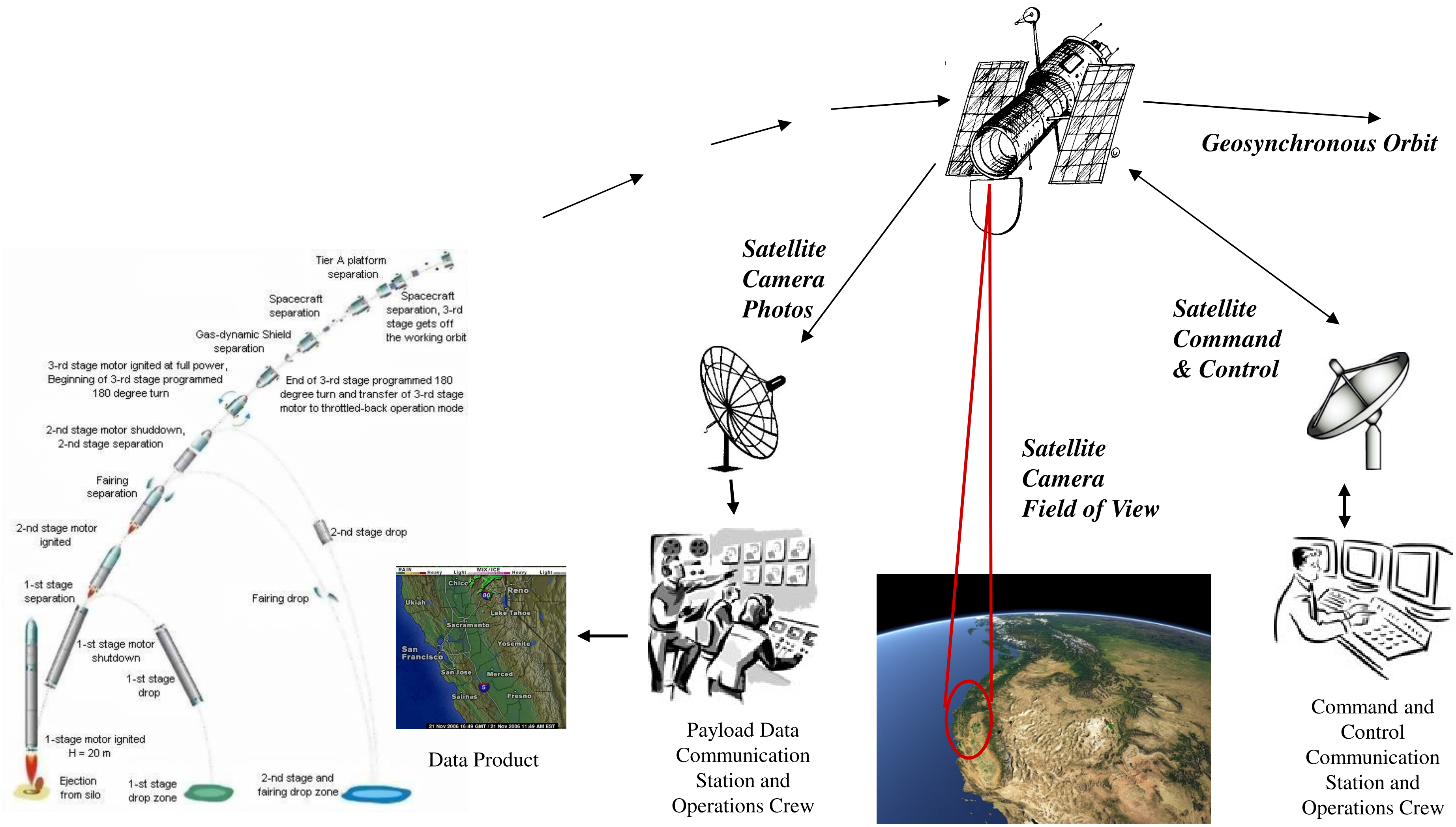





Space, ground & launch segments

- **"Segments"**: Distinctions between parts of a space system
  - **Space Segment**: satellite(s), orbit, orientation profile
  - **Ground Segment**: comm. station(s), operations centers, links
  - **Launch Segment**: launch vehicle, profile, deployment systems

- **"Mission Architecture"**: How the major parts of each segment work together to accomplish the mission

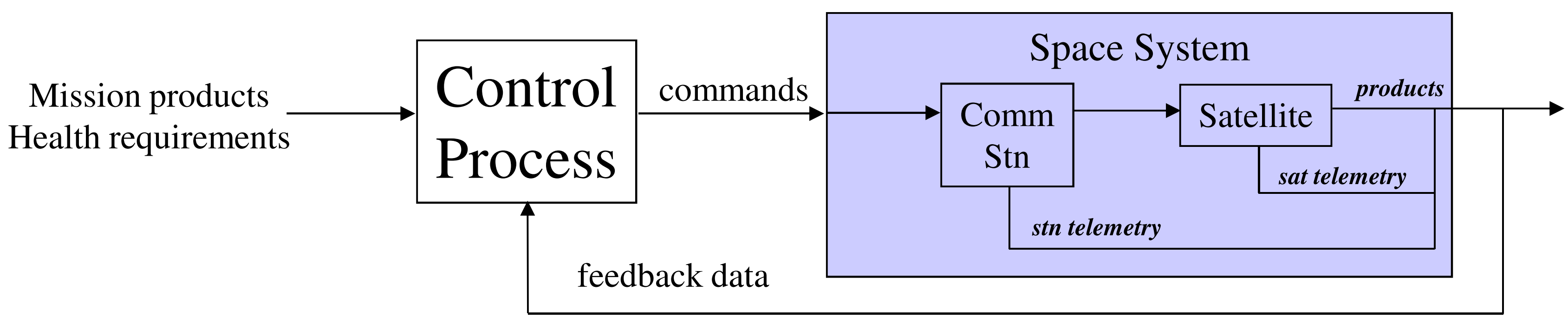
Space, ground & launch segments



Space System Control Process

- Purpose of space system control:
  - Generate & deliver mission products/services
  - Maintain health of the system
- How space system control is implemented:
  - Commands: Plan how to operate system over time (given resources), and then execut appropriate commands
  - Telemetry: Obtain data from system to estimate the state of the system and to verify proper operation

The satellite is NOT the ultimate product. The product is the mission data produced and delivered by the overall space system.



Satellite payload and bus

- "Bus" & "Payload": Distinction between parts of a satellite
- Payload: instrument or component producing the key product or service of interest
  - Camera and optics for a telescope
  - Broadband wireless transceiver for a communication service
  - Time generator and broadcast system for a navigation signal
- Bus: all of the other equipment required to support and protect the payload so that it can do its job (7 classical subsystems)
  - Orbital position sensing/control
  - Orientation (attitude) sensing/control
  - Power generation/storage/dist.
  - Temperature sensing/control
  - Command & data handling
  - Communications
  - Structural housing & mechanisms

Satellite Bus

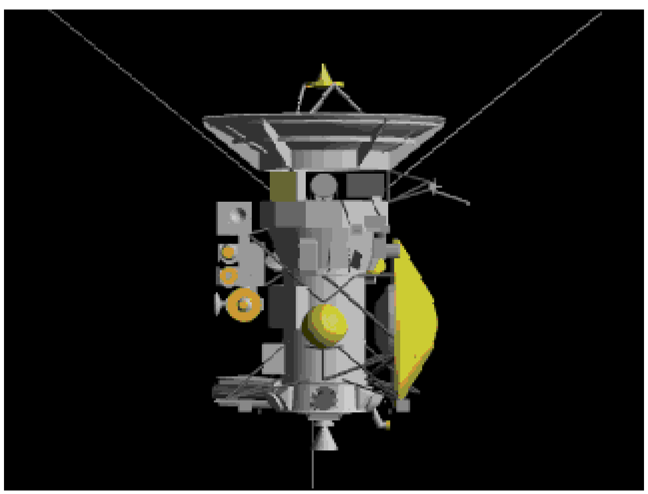
- Bus: What’s taken for granted with terrestrial instruments
- Case – astronomical observations
  - “payload” is the telescopic instrument
- Consider its support infrastructure
  - Geographic positioning
  - Structural mounting
  - Power
  - Pointing
  - Environmental Protection
  - Thermal control
  - Computer interface for scientists
- Consider the same issues if the telescope was put into orbit in order to exploit ‘above the atmosphere’

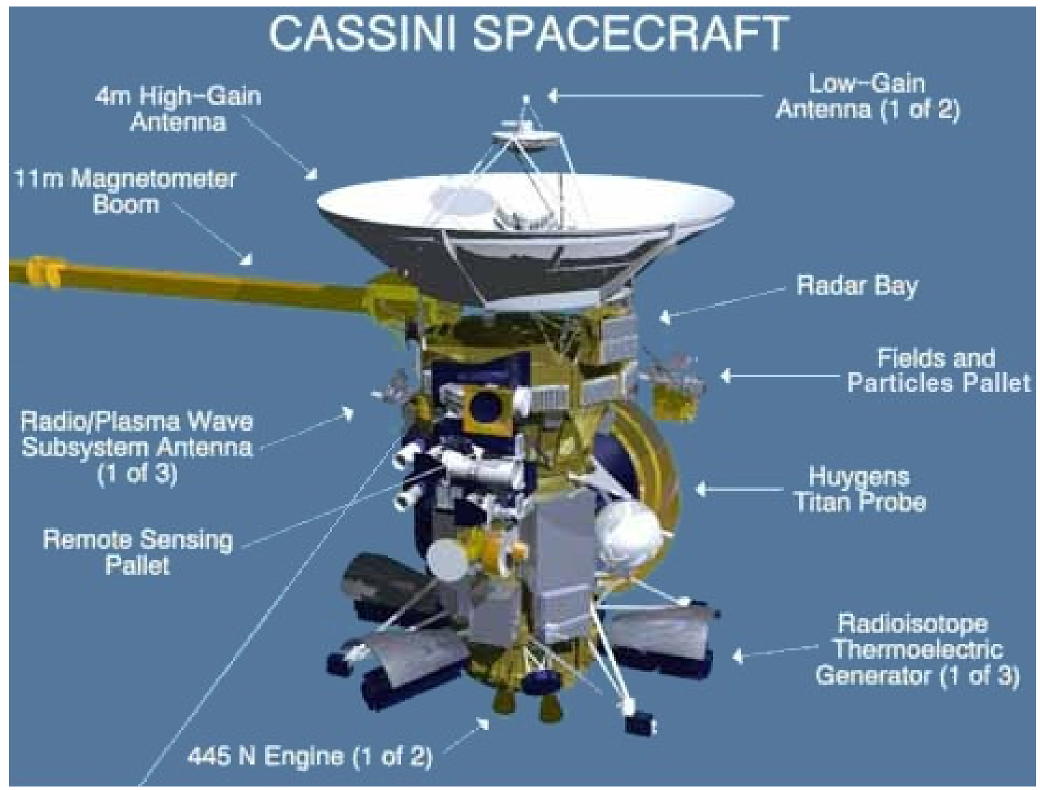
Satellite Bus –functions

- Bus: all of the other equipment required to support and protect the payload so that it can do its job (7 classical subsystems)
  - Orbital position sensing/control
    - What orbit should I be in, where am I, where do I need to be, how do I influence it?
  - Orientation (attitude) sensing/control
    - Where do I need to point, where am I looking, how do I influence my pointing?
  - Power generation/storage/dist.
    - How do I generate, store and distribute and manage power?
  - Temperature sensing/control
    - What are my temp requirements, how does heat flow, how do I sense and control?
  - Command & data handling
    - How do I package and interpret information to specify and report on activity?
  - Communications
    - How do I relay info between locations, often wirelessly, in an adequate manner?
  - Structural housing & mechanisms
    - How do I house, position and protect my components

Example spacecraft - Cassini

- Mission - Explore Saturn. Includes both an orbiter & probe
- Payloads: Images across spectrum; Field & particle instruments; Chem sensors…
- Bus: High gain (& 2 low gain) antennae for Earth communications; 3-axis stabilized (reaction wheels and thrusters); Thermal – louvers; Main rocket engine; Radioisotope thermoelectric generators (natural plutonium decay to generate heat for thermoelectric converters)



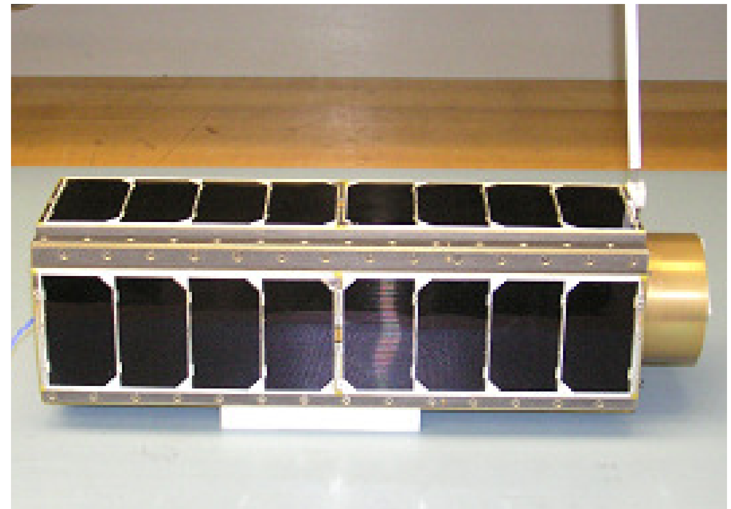


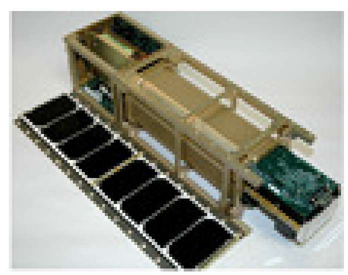
Example spacecraft – DSCS III

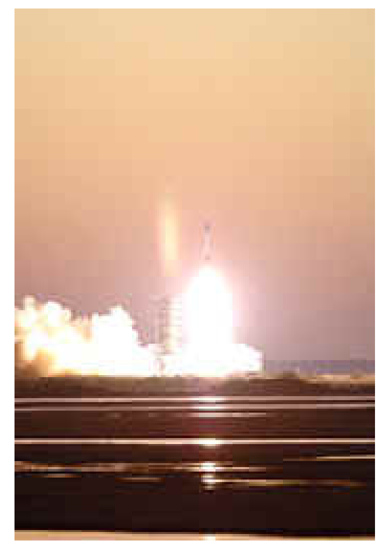
- Mission - Military communications
- Payload
  - Comm transceivers
  - Phased array antennae
- Bus
  - 3-axis stabilized w/sun & Earth sensors, 4 reaction wheels
  - Ground TEARR data orbit estimation w/thrusters
  - Deployable solar panels and NiCAD batteries
  - SGLS cmd and tlm system
  - Aluminum structure
  - Passive and active thermal control

Example spacecraft – GeneSat-1

- Mission - Demonstrate advanced technology
  - Autonomous in situ biological processing
- Payload
  - Biological experiment package that included optical instrumentation and a microfluidic system for providing nutrients to the biology
- Bus
  - Ga/As solar panels and Li-ion battery
  - 2.4 GHz ISM transceiver and ham radio beacon
  - Passive and active thermal control
  - Passive attitude control: magnets and hysteresis rods
  - NORAD orbit estimation and no propulsion



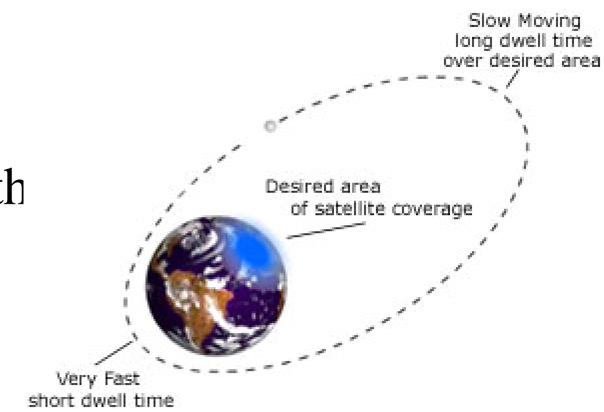




Challenge: Space Environment

- We have lectures on several of these issues….
- Microgravity – lack of contact forces, fluid management, etc.
- Radiation – total dose, SEUs, charging, sputtering, etc.
- Vacuum – outgassing, cold-welding, no convection, leaks, etc.
- Debris – impact issues and maneuvering requirements, etc.
- Atomic oxygen – oxidation of surfaces
- Force and Torque Disturbances
  - Atmospheric effects – drag
  - Magnetic Field - torques
  - Solar Pressure – torques and forces
  - Gravity gradients - torques

Challenge: Orbital motion



- We'll have a lecture on this issue as well….
- The basic concept
  - Satellites ideally move in ellipses about the Earth
  - The closer to the Earth, the faster they move
  - The Earth is rotating at the same time
- The resulting challenge
  - There often are competing choices regarding
    - Distance from Earth (think resolution, delay, power, etc.)
    - A moving field of view (think payload needs and comm support needs)
  - The nature of the mission influences the choice of orbit
    - What if you simply wanted to direct broadcast television?
    - What if you wanted high resolution imagery?
    - What if you wanted high res imagery – the whole Earth – all the time?
    - What if you just wanted to do a quick space-rated technology test?

Challenge: Orbital motion

- A few typical and very “convenient” orbit geometries…
- Moderately inclined Low Earth Orbit - LEO
  - Inexpensive, 90 min period, fly over middle latitudes in staggered manner
- Geosynchronous Earth Orbit (GEO)
  - Far away, “hovering” over a location on the equator
- Coordinated constellation
  - GPS – trade Earth coverage with signal geometry (24 in MEO [16,500 mi])
  - Iridium – trade coverage with delay and power (66 in LEO [485 mi])
- Sun Synchronous
  - Highly inclined LEO in which perturbations cause the orbital plane to rotate in synch with the Earth’s rotational travel about sun (ex: 98 deg and 600 km)
  - Useful for Earth observing, given that the illumination angle is conserved (the orbit passes over a location at the same local solar time)

Challenge: Orbital motion

- Simulation Example Using NOVA