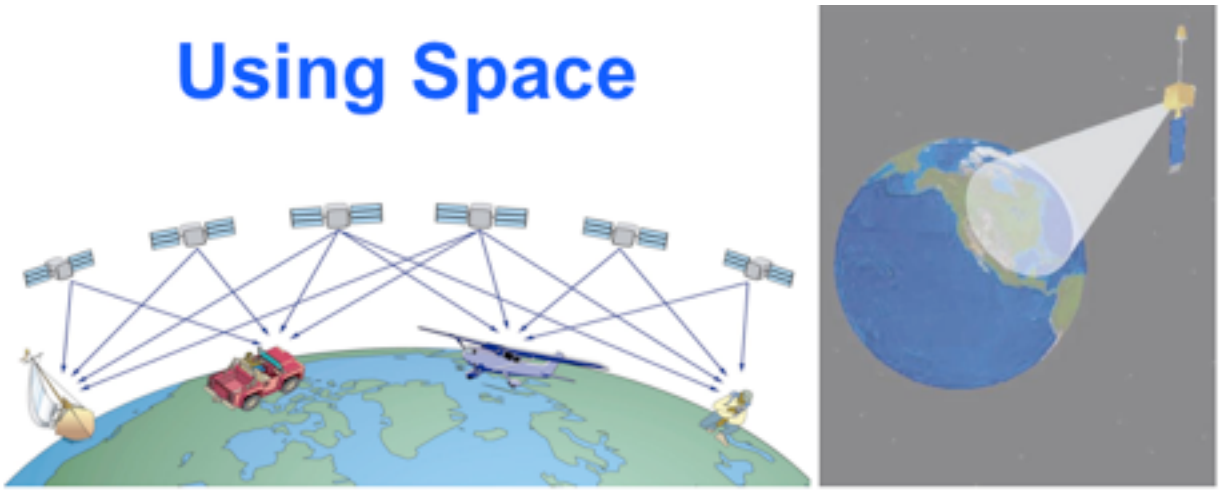
An Introduction to Astronautics and Space Systems

Block 1 Study Guide



Lesson 1 - Using Space

Review

- Space offers several unique advantages - The Space Imperative - that make its exploration essential for modern society
  - Global perspective
  - A clear view of the universe without the adverse effects of the atmosphere
  - A free-fall environment
  - Abundant resources
  - A final frontier
- Since the beginning of the space age, a wide variety of missions have evolved to take advantage of space
  - Communications satellites tie together remote regions of the globe
  - Remote-sensing satellites observe the Earth from space, providing weather forecasts, essential military information, and valuable data to help us better manage Earth's resources Navigation satellites revolutionize how we travel on Earth
  - Space observatories peer to the edge of the universe and study the dynamic nature of the sun
  - Scientific spacecraft explore the Earth and the outer reaches of the solar system and peer to the edge of the universe
  - Manned missions provide valuable information about living and working in space and experiment with processing important materials

Key Terms

- Communication
- Geostationary
- Free fall
- Navigation
- Remote sensing

Lesson 1 - Mission Problems

1. List the five unique advantages of space that make its exploitation imperative for modern society.

2. What are the four primary space missions in use today? Give an example of how each has affected, or could affect, your life.

3. Match the following terms with the appropriate statement below: free-fall, remote-sensing, navigation, and communications.

a. falling under the influence of gravity, free from any other forces
b. these satellites tie together remote regions of the globe
c. determining where you are and where you are going
b. gathering information about the nature and condition of Earth's land, sea and atmosphere

4. Define the following terms:

Scintillation

Geostationary

Lesson 2 - Elements of a Space Mission

Review

- Central to understanding any space mission is the mission itself, its scope tells us
  - The need describes the capability being delivered,
  - The goals and objectives lay out the expectations of the stakeholders,
  - The Concept of Operations or ConOps documents how systems and users will interact
- A space mission architecture includes the following elements
  - The spacecraft—composed of the payload that performs the mission and the bus that provides essential housekeeping and other support functions
  - The trajectories and orbits—the path the spacecraft follows through space. This includes the orbit (or racetrack) the spacecraft follows around the Earth.
  - Launch vehicles—the rockets which propel the spacecraft into space and maneuver it along its mission orbit
  - The mission operations systems—the "glue" that holds the mission together. It consists of all the infrastructure needed to get the mission off the ground, and keep it there, such as manufacturing facilities, launch sites, communications networks, and mission operations centers.
  - Mission management and operations—the brains of a space mission. An army of people make a mission successful. From the initial idea to the end of the mission, individuals doing their jobs well ensure the mission products meet the users' needs.

Key Terms

- astronautics
- constellation
- field-of-view
- flight-control team
- launch vehicle
- objective
- operations concept
- orbit
- parking orbit
- payload

space mission architecture
spacecraft bus
stages
swath width
thrusters
trajectory
transfer orbit
upperstage
users

Lesson 2 - Mission Problems

1. List the elements of a space mission.

2. List and describe the two basic parts of a spacecraft.

3. Match the following terms to the appropriate descriptions below: parking orbit, transfer orbit, swath width, and field-of-view

a. area of coverage on Earth's surface
b. temporary orbit where systems may be "checked out"
c. cone of visibility for a particular sensor
d. intermediate orbit that takes the spacecraft from its initial orbit to its mission orbit

4. Define the following terms:

Constellation

Operations Concept

Lesson 3 - A Brief History of Space

Review

- Several natural philosophers and scientists reformed our concept of space from 1500 to the 20th century
  - Copernicus defined a heliocentric (sun-centered) universe
  - Brahe vastly improved the precision of astronomical observations
  - Kepler developed his three laws of motion:
  - The orbits of the planets are ellipses with the Sun at one focus
  - Orbits sweep out equal areas in equal times
  - The square of the orbital period is proportional to the cube of the mean distance from the Sun
  - Galileo developed dynamics and made key telescopic discoveries
  - Newton developed his three laws of motion and the law of universal gravitation
- Rockets evolved from military weapons in the 1200s to launch vehicles for exploring space after World War II
  - Sputnik-1, launched by the former Soviet Union on October 4, 1957, was the first artificial satellite to orbit Earth
  - Yuri Gagarin was the first human to orbit Earth on April 12, 1961
  - The space race between the United States and former Soviet Union culminated with the success of the Apollo Program
  - Today, space is an international endeavor that has revolutionized communication, navigation, remote sensing and our understanding of the Universe

Key Terms

- astronomy
- ballistic missile
- communication satellites
- degree
- Doppler
- eccentricity
- focus
- geocentric
- geostatic
- heliocentric
- light year
- minute of arc
- parallax
- perturbation
- relativity
- spectroscopy
- sublunar realm
- superlunar realm

Lesson 3 - Mission Problems

1. List four theories from Aristotle that Galileo disproved.

2. How did our concept of the universe change in the first few decades of the 20th century?

3. Match the following names with the correct statement below: Copernicus, Kepler, Brahe, and Newton

a. developed three laws of motions and the law of universal gravitation
b. one of his three laws states that orbits of planets are ellipses with the Sun at one focus
c. defined a heliocentric (sun-centered) universe
d. vastly improved the precision of astronomical observations

4. Define the following terms:

Eccentricity

Perturbation

Heliocentric

Lesson 4 - The Space Enterprise

Review

- The Space Enterprise landscape includes 3 key sets of players:
  - Government - Role of sponsor, executive agent and developer of technologies
  - Industry - Builds, tests, launches space systems
  - Users and Operators - Define mission needs, benefit from missions, keep them flying
- Combinations of these players work together on 3 major tasks for each space mission
  - Systems Engineering - Designing, Building and Managing the technical effort
  - Mission Management - Leading and managing the total effort from cradle to grave
  - Space Operations - Planning and conducting the mission to deliver services to users
- In recent years, the space industry has seen 4 major trends:
  - The New High Ground - Increased military dependance on space
  - Globalization - Increased international cooperation and competition
  - Commercialization - Growth of commercial space ventures to nearly half of all space spending
  - Capital market acceptance - Ability for commercial space ventures to raise money from traditional sources

Key Terms

- capital market acceptance
- commercialization of space
- globalization
- mission management
- space operations
- systems engineering

Lesson 4 - Mission Problems

1. List and briefly describe the three major players that make up the Space Enterprise landscape.

2. List and describe emerging trends in the space industry.

3. Match the following with the appropriate descriptions below: the Acquisition Process, Systems Engineering, Mission Management, and Space Operations.

a. leading and managing the total effort from cradle to grave
b. designing, building and managing the technical effort
c. planning and conducting the mission to deliver services to others
d. all of the tools, techniques and review steps required for turning needs into capabilities

4. Define the following:

Space Force Enhancement

Space Support

Space Control-Counterspace

Space Force Application

Lesson 5 - Space Systems Engineering

Review

- Systems Engineering is one of 3 major mission tasks needed to develop and sustain space missions
  - A "system" is an integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective
- Systems Engineering is a Framework of interrelated activities that spans Design, Management and Realization of systems
- Systems engineering depends on both technical leadership - the art -and systems management - the science
  - The SE universe has 4 dimensions - cost, schedule, performance and risk
  - Design - starts with mission scope and iterates to converge on a detailed system definition that someone can build
  - Realization - includes buying, building or reusing the pieces that make up the system, then assembling and integrating them. Includes both verification and validation activities.
  - Manage - Risk, requirements and interfaces
- During the mission lifecycle, a project goes through a number of technical baselines as it matures

Key Terms

- design
- interfaces
- manage
- payload
- realization
- requirements
- risk
- subject
- system

Lesson 5 - Mission Problems

1. List and briefly describe the three parts of the Systems Engineering Framework.

2. List the four dimensions of the Systems Engineering Universe.

3. Match the following terms with the best description below: Requirements, Interfaces, and Risk

a. defined in two dimensions, probability of occurrence and consequence OR sources include poorly defined technical tasks or cost estimations, poorly defined requirements and interfaces, low technological maturity, unrealistic project planning or inadequate resources and inadequate workforce skill level.

b. single, verifiable shall statements that address both characteristics as well as capabilities

c. connect one piece to another within mechanical, electrical, and thermal subsystems

4. Define the following terms:

System

Technical Leadership

Systems Management

Lesson 6 - Mission Management

Review

- Mission Management covers the personnel and project control tools needed to get a mission started and keep it moving on schedule and within budget
  - Team management includes:
    - Establishing effective team communication and decision-making processes
    - Developing the norms for the team, the level of team cohesion, and the methods for conflict resolution
  - Project Control tools and techniques include:
    - Work breakdown structures - systematic hierarchy of system elements
    - Project Scheduling - using network modeling to determine the relationship between elements in the work breakdown structure
    - Performance metrics - methods for keeping track of the project's "pulse"
    - Documents - the means for capturing the key project design and management decisions
    - Reviews - how decision makers learn if the project is on track and should continue to be funded

Key Terms

- autonomy
- commissioning
- critical path
- design-for-manufacture
- design-to-cost
- earned value
- gantt chart
- integrated master schedule
- launch-readiness review
- metrics
- mission-operations team
- mission timeline
- simulations
- slack
- team norms
- work breakdown structure

Lesson 6 - Mission Problems

1. List and briefly describe the two categories of team management tasks.

2. List characteristics of effective project performance indicators.

3. Match the following terms with the best description below: Metrics, Schedule, Key Documents, and Technical Reviews

a. Serve to capture the decisions and activities throughout the lifecycle

b. Seek to determine if the proposed actions, resources and funding are adequate to successfully execute the next stage

c. Uses network modeling to determine the relationship between elements in the Work Breakdown Structure

d. Tell us “how it’s going”

4. Define the following terms:

Work Breakdown Structure

Earned Value Management

Lesson 7 - Space Operations

Review

- Space operations tasks include:
  - Mission Planning and Analysis
  - Simulations and Training
  - Flight Control
  - System Maintenance and Support
  - Data Processing and Handling
- Mission operations systems includes the facilities and infrastructure to design, assemble, integrate, test, launch, and operate a space mission
  - Spacecraft manufacturing
  - Launch
  - Operations
- The Operations Concept describes how we plan to use the system to fulfill the mission. Key trade-offs include:
  - Spacecraft autonomy
  - Ground station automation
  - Ground station staffing
  - Anomaly response
  - State-of-health monitoring
  - New or existing hardware/software

Key Terms

- commands
- communication
- communication architecture
- control center
- crosslink
- downlink
- forward link
- ground stations
- ground support equipment (GSE)
- mission operations systems
- receiver
- relay satellites
- return link
- signal
- signal strength
- spacecraft
- telemetry
- transmitter
- uplink

Lesson 7 - Mission Problems

1. List and briefly describe five broad categories of Space Operations Tasks.

2. List Key Space Operations Trade-Offs.

3. Match the following terms with the best description below: Spacecraft, Ground Stations, Control Center and Relay Satellites.

a. Additional spacecraft that link the primary spacecraft with ground stations

b. Earth-based antennas, transmitters and receivers

c. The in-space element

d. Controls the spacecraft and all other elements in the network

4. Define the following terms:

Communication Architecture

Operations Concept Document

Lesson 8 - Down to Earth Issues

Review

- Governments pursue space activities for a variety of political motives
  - Promote national image and foreign policy objectives
  - Enhance national and regional security
  - Advance science and technology
  - Support national industries
- International space law derives from traditions and several space-related treaties. We can summarize these as seven basic principles:
  - International law applies to outer space
  - Obligation to use space for peaceful purposes only
  - Right to use outer space, but not to appropriate
  - Register space objects
  - State responsibility for and supervision of private activities
  - Retention of jurisdiction and control
  - Liability for damage
- The International Telecommunication Union (ITU), along with related national agencies, regulates the scarce frequency allocations to government and commercial space activities
- Cost is a key design variable
  - Life-cycle costs include costs incurred during all phases of a space mission: proposal, design, manufacture, launch, and operations.
  - Parametric cost estimation techniques to give us up-front and on-going estimates of mission and system

Key Terms

- cost estimating relationships (CERs)
- Federal Communications Commission (FCC)
- International Law
- International Telecommunications Union (ITU)
- liability
- national and regional security
- national image
- parametric cost estimation
- Pareto Principle
- Space Law
- Space Policy
- Technology Readiness Level (TRL)

Lesson 8 - Mission Problems

1. List and briefly describe the three branches of the Space Mission Triad.

2. List the seven principles of International Law.

3. Match the following terms with the best description below: Technology Readiness Level (TRL), International Traffic in Arms Regulations (ITAR), National Telecommunication and Information Administration (NTIA) and Federal Communications Commission (FCC)

a. These state that US Space Technology cannot be shared with non-US persons without authorization from the Department of State.

b. A common metric used to determine where a technology is on its journey from idea to flight.

c. An organization that manages frequency allocation for operations over U.S. territory

d. A frequency plan developed by local command or agency frequency coordination body is coordinated with this organization for all government frequency assignments

4. Define the following terms:

Pareto Principle

Analogy-based estimating

Parametric estimating

