HokieSpace, Inc.
Functional Divisions

There are five functional divisions, each responsible for areas listed below.

D&C: O&A (Dynamics and Control: Orbits and Attitude): Astrodynamics, Mission Analysis, Mission Geometry, and Guidance and Navigation; Attitude Determination and Control System

D&C: Prop (Dynamics and Control: Propulsion): In-space propulsion for orbit transfer, stationkeeping, and attitude control

S&LV (Structures and Launch Vehicle): Structural Analysis and Design; Mechanisms; Engineering Drawings; Mass Budget; Launch Vehicle Comparison and Selection

PT&E (Power, Thermal, and Environment): Power System; Power Budget; Thermal Analysis; Environmental Effects

CC&DH (Communications; Command and Data Handling): Radio Communications System; Computer System; Telemetry; Command and Data Handling

The functional divisions are responsible for

- preparing a series of Technical Reports
- giving presentations in January 2006
- updating the information in the attached pages

The technical reports should follow the format shown in the handout titled Functional Division Report Format. The chapters are due periodically throughout the semester, with the final report due just before Thanksgiving.

The functional presentations will be given the week after Thanksgiving.

The motivation for this assignment is based on these specific ideas:

- You all need to learn at least one area of space systems in more detail than you'll get from the class, or even from your project
- Learning about, say, space power hardware, is easier if you share the responsibility for gathering information among several people
- This course is on the university's "Writing Intensive" list, so you need to get more writing opportunities

D&C: Dynamics and Control Functional Division

Astrodynamics, Mission Analysis, Mission Geometry, and Guidance and Navigation

Functional Division Responsibilities:

Identify orbit types
Determine influence of orbit design on other subsystems and vice versa
Determine relationships between mission performance and orbit selection
Develop graphical representations of orbits, coverage, and access
Complete orbit design trade studies
Develop ΔV budget
Develop orbit determination and orbit maintenance concepts
Estimate related subsystem mass, cost, and power
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other functional divisions
Document analysis and decisions

Interacts strongly with

Communications, Computer, Ground Systems, Mission Operations, Power, Space Environment, Thermal

Questions

How does this functional area interact with other functional areas?
What different phases of the mission have different orbit requirements?
Which orbits give the best performance?
How do different orbits affect choices for ADCS, power, *etc*?
What do you need to know from other functional divisions?

References

Agrawal, Ch. 2
BM&W
Brown
F&S, Chs. 1, 3, 4, and 5
G&F, Chs. 2 and 4
HH&L
L&W, §4.2, Chapters 5, 6, 7, §§8.1.5, 11.7
P&M, Ch. 3
Vallado

Tools

FreeFlyer, Satellite Toolkit, WinOrbit

D&C: Dynamics and Control Functional Division

Attitude Determination and Control System (ADCS)

Functional Division Responsibilities:

Identify ADCS requirements
Define control modes
Quantify disturbance torque environment
Identify alternative ADCS approaches
Define ADCS algorithms
Estimate subsystem mass, cost, and power
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

Astrodynamics, Communications, Cost, Environment, Operations, Power, Propulsion, Structures, Thermal

Questions

How do other subsystems affect ADCS design?
How do mission requirements affect ADCS design?
What new technologies might improve ADCS performance in the near future?
What do you need to know from the other Functional Divisions?

References

Agrawal, Ch. 3
F&S, Chs. 3 and 10
G&F, Ch. 7
L&W, §10.4.2, §11.1
P&M, Ch. 5
Wertz

Tools

Spacecraft Control Toolbox

D&C: Dynamics and Control Functional Division

Propulsion

Functional Division Responsibilities:

Develop propellant budget
Identify alternatives
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

ADCS, Astrodynamics, Environment, Launch, Operations, Power, Structures, Thermal

Questions

How does this subsystem interact with other subsystems?
What types of propulsion systems are available?
What different phases of the mission have different propulsion requirements?
What types of propulsion systems can be replaced with other types of actuators?
How does changing the spacecraft performance requirements affect the design of this subsystem?
What do you need to know from other Functional Divisions?

References

F&S, Ch. 6
G&F, Ch. 5
L&W, §§4.2, 10.3, 10.4.1, 10.4.2, 11.1, Chs. 6, 7, 17
P&M, Ch. 4
HH&L

Tools

S&LV: Structures and Launch Vehicle Functional Division

Structures and Mechanisms

Functional Division Responsibilities:

Identify structural requirements by mission phase
Identify primary structure options
Size primary structure members
Identify all requirements for mechanisms and deployables
Estimate subsystem mass, cost, and power
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

ADCS, Communications, Environment, Launch, Operations, Power, Propulsion, Thermal

Questions

What materials are best for constructing spacecraft?
What mechanisms are used by other subsystems?
What drives the primary structural design?
What manufacturing techniques are applicable to the structure?
What do you need to know from the other Functional Divisions?

References

Agrawal, Chs. 1 and 4
F&S, Chs. 9 and 16
G&F, Ch. 8
L&W, §11.6
Outgassing
P&M, Ch. 8
Sarafin

Tools

I-DEAS
AutoCAD

S&LV: Structures and Launch Vehicle Functional Division

Launch Vehicle Selection

Functional Division Responsibilities:

Identify launch requirements
Develop a descriptive scenario and graphical representation of launch and deployment
Identify candidate launch vehicles and their environments
Determine spacecraft design envelope (stowed)
Determine if an upper stage is needed
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

ADCS, Astrodynamics, Cost, Economic, Environment, Ground Systems, Operations, Power, Propulsion, Structures, Thermal

Questions

What launch vehicles are available?
What are the LVs' capabilities?
What makes a "good" launch vehicle?
What do you need to know about your spacecraft in order to select a launch vehicle?

References

Agrawal, §1.3
F&S, Chs. 6 and 7
G&F, Ch. 5
L&W, Chs. 17 and 18
P&M, Ch. 4

Tools

PT&E: Power, Thermal and Environment Functional Division

Power

Functional Division Responsibilities:

Develop a power budget with inputs from other Functional Divisions
Model BOL and EOL power collection and energy storage requirements
Determine power required during sunlight and eclipse
Compute charge-discharge cycle rates and number of cycles
Determine depth of discharge
Develop a simulation of a typical orbit power cycle
Evaluate degradation over satellite lifetime
Select solar cell and battery types
Select solar panel configuration
Evaluate power regulation approaches
Develop detailed block diagram of PMAD subsystem
Estimate subsystem mass and cost
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

ADCS, Astrodynamics, Environment, Launch, Operations, Structures, Thermal

Questions

What are the primary components of the power subsystem?
How do other subsystems affect the power system design?
What new technologies are likely to impact power system design in the near future?
What do you need to know from other Functional Divisions?

References

Agrawal, Ch. 6
F&S, Ch. 11
G&F, Ch. 10
L&W, §§4.2, 9.4.1, 10.2, 10.3, 10.4.6, 11.4
P&M, Ch. 6

Tools

PT&E: Power, Thermal and Environment Functional Division

Thermal

Functional Division Responsibilities:

Understand the thermal environment of the spacecraft
Determine temperature constraints for spacecraft components
Develop a thermal model
Evaluate worst-case cold and hot conditions
Evaluate alternatives for controlling temperature
Select surface coatings, insulations, radiators
Estimate subsystem mass, cost, and power
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

ADCS, Astrodynamics, Communications, Computer, Cost, Economic, Environment, Ground Systems, Launch, Operations, Power, Propulsion, Structures, Thermal

Questions

What subsystems affect the thermal design?
What do you need to know from other Functional Divisions in order to design the thermal subsystem?
What approaches to thermal design are available?
What materials are available?

References

Agrawal, Ch. 5
F&S, Ch. 12
G&F, Ch. 9
L&W, Chs. 5, 6, 7, §11.7
P&M, Ch. 7

Tools

NEVADA
I-DEAS

PT&E: Power, Thermal and Environment Functional Division

Space Environment

Responsibilities:

Understand the space environment and its effects on spacecraft performance
Model single-event upsets
Model outgassing
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other functional divisions
Document analysis and decisions

Interacts strongly with

Astrodynamics, Communications, Computer, Ground Systems, Mission Operations, Power, Thermal

Questions

How do the environmental issues depend on orbit selection?
How does the environment affect different subsystems?
What do you need to know from other functional divisions in order to evaluate environmental effects?

References

F&S, Ch. 2
G&F, Ch. 3
L&W, Ch. 8
P&M, Ch. 2
Tascione
Outgassing Data

Tools

The Environment WorkBench (EWB)

CC&DH: Communications, Command & Data Handling Functional Division

Communications

Functional Division Responsibilities:

Develop a link budget
Select frequencies
Select receivers, transmitters, and antennas
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Estimate subsystem mass, cost, and power
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

ADCS, Astrodynamics, Computer, Economic, Environment, Ground Systems, Operations, Power, Structures

Questions

How do other subsystems affect communications?
What do you need to know from the other Functional Divisions?
What new technologies might impact comm system design in the near future?

References

Agrawal, Ch. 7
F&S, Chs. 13 and 17
G&F, Ch. 11
L&W, §§4.2, 10.4.3 and 11.2, Chs. 13 and 15
P&M, Ch. 9

Tools

CC&DH: Communications, Command & Data Handling Functional Division

Computer, Command and Data Handling, and Telemetry

Functional Division Responsibilities:

Define computer system modes and states
Develop computer system state diagram
Partition and allocate computational functions to space, ground, subsystem, hardware, software
Develop functional partitioning diagram
Evaluate interfaces and candidate architectures
Evaluate data bus candidates
Develop functional flow diagram
Develop data flow diagram
Develop alternative block diagrams for candidate architectures
Estimate software size and throughput
Estimate subsystem mass, cost and power
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

ADCS, Astrodynamics, Communications, Computer, Cost, Economic, Environment, Ground Systems, Launch, Operations, Power, Propulsion, Structures, Thermal

Questions

What computers are usually used on spacecraft?
What properties of a computer make it a good flight computer?
How does computer selection depend on the other subsystems?
What do you need to know from other Functional Divisions?
What data formats are needed for commands, data, and telemetry?

References

F&S, Chs. 14 and 15
G&F, Ch. 11
L&W, §§10.4.4, 11.2, 11.3, Ch. f16
P&M, Chs. 10 and 11

Tools

Other Functional Areas That Impact Spacecraft Design Projects

Payloads

Functional Division Responsibilities:

Understand optical payload characteristics
Complete a subject trade study
Develop pointing and mapping budgets
Identify alternative payloads to accomplish mission objectives
Estimate payload mass, cost, and power
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

ADCS, Astrodynamics, Communications, Computer, Cost, Economic, Environment, Operations, Power, Structures, Thermal

Questions

Who decided the payload requirements?
If the payload requirements were a small amount less demanding, would there be a significant decrease in system "cost"? (*i.e.*, mass, complexity, *etc.*)
How do the payload requirements affect other subsystems?
How do other subsystem designs affect payload design?

References

F&S, Ch. 1
L&W, §§4.2 and 5.4, Ch. 9

Tools

Other Functional Areas That Impact Spacecraft Design Projects

Cost Modeling and Reliability

Functional Division Responsibilities:

Develop a cost breakdown structure
Develop a parametric cost estimation
Develop a reliability estimate
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

Everything

Questions

How will you model cost?
What information will you need from others to develop a cost model?
How will you model reliability?
What information will you need from others to develop a reliability model?

References

F&S, Ch. 18
L&W, Chs. 19, 20, 22
P&M, Ch. 13
W&L (RSMC)

Tools

Space Operations Cost Model
Small Spacecraft Cost Model

Mission Operations and Ground Systems

Functional Division Responsibilities:

Identify spacecraft characteristics
Identify operations team functions
Identify lifecycle operations timeline
Identify pass operations timeline
Identify interfaces with other operations centers
Identify ground system functions
Identify number and location of ground stations
Develop a block diagram for the ground system
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

ADCS, Astrodynamics, Communications, Computer, Cost, Environment, Launch, Power, Propulsion, Structures, Thermal

Questions

How will the space system be operated?
How many people will it take?
What effects do different subsystem designs have on operational complexity?
How are functions divided between space and ground segments?
How much autonomy does the system have?

References

F&S, Ch. 15
L&W, Chs. 14 and 15
P&M, Ch. 14

Tools

Other Functional Areas That Impact Spacecraft Design Projects

Economic, Political and Legal Systems

Functional Division Responsibilities:

Understand space law and policy
Identify current economic trends in the space industry
Identify relevant agencies and regulations
Identify insurance practices
Identify import and export restrictions
Identify responsibilities of spacecraft owners
Learn to use appropriate modeling and analysis tools
Develop additional modeling and analysis tools as needed
Communicate with other Functional Divisions
Document analysis and decisions

Interacts strongly with

Astrodynamics, Communications, Cost, Ground Systems, Launch, Operations, Power

Questions

What are the right questions to ask?

References

L&W, Ch. 21
Journal of Space Law

Tools

Other Functional Areas That Impact Spacecraft Design Projects

Program Management

Responsibilities:

Develop and maintain project schedule
Develop work breakdown structure
Identify and track action items
Schedule and run meetings

References

F&S, Ch. 19
Garner, Chs. 1, 6, and 7
G&F, Ch. 1
L&W,
P&M, Chs. 1 and 13

References

- *Outgassing Data for Selecting Spacecraft Materials*, Online at http://misspiggy.gsfc.nasa.gov/og/
- B. N. Agrawal, *Design of Geosynchronous Spacecraft*, 1986, Prentice-Hall.
  This book is about communication satellites. It includes chapters on communications and electronics, orbital and attitude dynamics as well as structural dynamics and thermal control.
- A.I.A.A., *Design for On-Orbit Spacecraft Servicing*, 1991, AIAA.
  This is a proposed guide with very detailed guidelines and methodology.
- C. D. Brown, *Spacecraft Mission Design*, 2nd edition, 1998, AIAA.
- P. Fortescue and J. Stark (editors), *Spacecraft Systems Engineering*, 2nd edition, 1997, Wiley. Like SMAD, this book is written by a variety of experts and covers many of the same topics.
- J. T. Garner, *Satellite Control*, 1996, Wiley.
- M. D. Griffin and J. R. French, *Space Vehicle Design*, 1991, AIAA.
  Similar to Agrawal's book, but with more on propulsion.
- R. W. Humble, G. N. Henry, and W. J. Larson, *Space Propulsion Analysis and Design*, 1995, McGraw-Hill.
- V. L. Pisacane and R. C. Moore (editors), *Fundamentals of Space Systems*, 1994, Oxford U. Press. This is a useful reference covering a wide range of topics related to space system analysis, design, test, integration and operations. This covers some of the same technical material as Larson and Wertz, but in more detail.
- T. P. Sarafin (editor), *Spacecraft Structures and Mechanisms*, 1995, Microcosm. As in the other volumes of the Space Technology Library, the emphasis here is on putting the relevant technical information into a form that can be used immediately by practicing space systems engineers.
- T. F. Tascione, *Introduction to the Space Environment*, 1988, Krieger.
- D. A. Vallado, *Fundamentals of Astrodynamics and Applications*, 1997, McGraw-Hill.
- D. H. Waltz, *On-Orbit Servicing of Space Systems*, 1993, Krieger.
  This book gives extensive coverage of the design and operations concepts required for spacecraft planned for on-orbit construction and servicing.
- J. R. Wertz, editor, *Spacecraft Attitude Determination and Control*, 1978, D. Reidel.
  This is a monumental tome written by many people. It is quite application-oriented, with many examples.
- J. R. Wertz and W. J. Larson (editors), *Reducing Space Mission Cost*, 1996, Microcosm.
  "Reducing mission cost is hard enough if you know what the real costs are, and virtually impossible if you don't."